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(54) COMMUNICATION OF TRAIN ON-BOARD CONDITION MONITORING DATA

(57) A method of communicating on-board condition monitoring data from a train to a ground-side database id provided. The method includes repeatedly collecting sensor readings from respective on-board equipment items of the train. The method further includes forming plural time series for each of the on-board equipment items, each time series being values of a status signal equal to or derived from the sensor readings of the respective on-board equipment item and spaced at a given time interval, the plural time series being assigned to respective groups on the basis that the status signals of the time series of each group are functionally related such that, at at least some time intervals, when the value of the status signal of one time series of a given group changes, the values of the status signals of the other time series of the given group are also expected to change. The method further includes on each time interval: comparing the values of the status signals of the plural time series at the current time with the values of the status signals of the plural time series at the preceding time; and producing a data packet for transmission only when at least one of the status signals of the plural time series is a changed status signal in which its value at the current time differs from its value at the preceding time, the data packet including, in a predetermined order, the following contents: the current value of the changed status signal, the current values of the status signals of the other time series of the group which contains the changed status signal, a unique identifier identifying that group, and a timestamp providing the current time. The method further includes transmitting each produced data packet to the ground-side database The method further includes recording the contents of each transmitted data packet at predefined locations in the database according to their predetermined order.

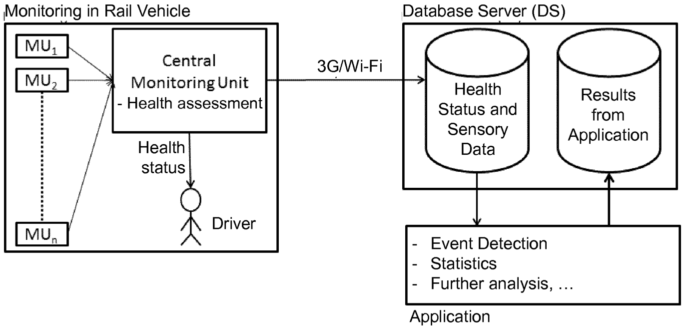

Fig. 1

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Description

Field of the Invention

[0001] The present invention relates to a method of communicating on-board condition monitoring data from a train to a ground-side database, and to an on-board system for communicating condition monitoring data from a train to a ground-side database.

Background

[0002] With the evolution of IT and communications systems, Condition Monitoring (CM) systems have become widely used in recent years on trains.

[0003] A typical CM system collects sensor readings from a rail vehicle and uses these readings to generate health indicators to inform the operator (driver) of ongoing issues relating to the vehicle. CM systems can also send sensor readings to ground-side databases, using media such as 3G or WiFi, for more detailed ground-side analysis.

[0004] To have a full understanding of equipment behaviour, sensor readings may be collected at high frequencies. However, in general the values of the readings do not change very often, such that much of the generated data is redundant. Thus to avoid overloading communication and storage systems, and to reduce the cost of such systems, it is desirable to promote forms of lossless compression for transmitting and storing train CM data.

Summary

[0005] In general terms, the present invention provides a method and an on-board system for communicating condition monitoring data from a train to a ground-side database in which data is grouped into packets including related status signal values. This approach to communication can help to reduce transmission and storage burdens while improving database performance.

[0006] For example, if the train has plural similar or identical equipment items which are expected to operate at the same time, then status signals of those items can be grouped according to function.

[0007] Accordingly, in a first aspect, the present invention provides a method of communicating on-board condition monitoring data from a train to a ground-side database, the method including:

> repeatedly collecting sensor readings from respective on-board equipment items of the train;
> forming plural time series for each of the on-board equipment items, each time series being values of a status signal equal to or derived from the sensor readings of the respective on-board equipment item and spaced at a given time interval, the plural time series being assigned to respective groups on the basis that the status signals of the time series of each group are functionally related such that, at at least some time intervals, when the value of the status signal of one time series of a given group changes, the values of the status signals of the other time series of the given group are also expected to change;
> on each time interval:
>
> > comparing the values of the status signals of the plural time series at the current time with the values of the status signals of the plural time series at the preceding time, and
> > producing a data packet for transmission only when at least one of the status signals of the plural time series is a changed status signal in which its value at the current time differs from its value at the preceding time, the data packet including, in a predetermined order, the following contents: the current value of the changed status signal, the current values of the status signals of the other time series of the group which contains the changed status signal, a unique identifier identifying that group, and a timestamp providing the current time;
>
> transmitting each produced data packet to the ground-side database; and
> recording the contents of each transmitted data packet at predefined locations in the database according to their predetermined order.

[0008] Advantageously, by producing each data packet only when at least one of the status signals is a changed status signal, it is possible to avoid transmitting data packets at every time interval, and thus it is possible to significantly reduce the transmission and storage burden. However, the method of the first aspect goes further than that by giving the data packet a predetermined order. In this way, although more status signal data are transmitted in any given packet than would be the case if only the changed status signal were transmitted, the overall amount of transmitted data can nonetheless be significantly reduced because fewer identifier data are needed. Also, the predetermined order of the packet enables the database to correctly allocate the contents of the packet with low database input/output (I/O) costs. Additional transmission efficiencies can be obtained because the functional relation between status signals means that any given packet may include values for plural changed status signals.

[0009] Preferably, in the method of the first aspect, each group includes the time series of plural substantially identical on-board equipment items (e.g. doors of the train). Preferably, in the method of the first aspect, the status signals of the time series of each group are functionally related such that at any time interval when the value of the status signal of one time series of a given group changes, the values of the status signals of the other time series of the given group are also expected to change.

[0010] Rather than grouping the status signals in the produced data packet according to function, another option is to group them according to the on-board equipment item from which they derive.

[0011] Accordingly, in a second aspect, the present invention provides a method of communicating on-board condition monitoring data from a train to a ground-side database, the method including:

- repeatedly collecting sensor readings from respective on-board equipment items of the train;
- forming plural time series for each of the on-board equipment items, each time series being values of a status signal equal to or derived from the sensor readings of the respective on-board equipment item and spaced at a given time interval;
- on each time interval:
  - comparing the values of the status signals of the plural time series at the current time with the values of the status signals of the plural time series at the preceding time, and
  - producing a data packet for transmission only when at least one of the status signals of the plural time series is a changed status signal in which its value at the current time differs from its value at the preceding time, the data packet including, in a predetermined order, the following contents: the current value of the changed status signal, the current values of the status signals of the other time series generated for the on-board equipment item from which the changed status signal derives, a unique identifier identifying that on-board equipment item, and a timestamp providing the current time;
- transmitting each produced data packet to the ground-side database; and
- recording the contents of each transmitted data packet at predefined locations in the database according to their predetermined order.

[0012] Again, although more status signal data are transmitted in any given packet than would be the case if only the changed status signal were transmitted, the overall amount of transmitted data can nonetheless be significantly reduced because fewer identifier data are needed. Also, the method provides similar advantages to the method of the first aspect in terms of quick and efficient updating in the ground-side database, and reduced database input/output (I/O) costs.

[0013] Preferably, in the method of the second aspect, the produced data packet relates to only one on-board equipment item. Accordingly, it may include only one unique identifier identifying the on-board equipment item.

[0014] In a third aspect, the present invention provides an on-board system for communicating condition monitoring data from a train to a ground-side database, the on-board system having:

- plural monitoring sensors configured to repeatedly collect sensor readings from respective on-board equipment items of the train; and
- a central monitoring unit configured to receive the sensor readings and thereby form plural time series for each of the on-board equipment items, each time series being values of a status signal equal to or derived from the sensor readings of the respective on-board equipment item and spaced at a given time interval, the plural time series being assigned to respective groups on the basis that the status signals of the time series of each group are functionally related such that when the value of the status signal of one time series of a given group changes, the values of the status signals of the other time series of the given group are also expected to change;
- wherein the central monitoring unit is further configured to perform on each time interval:
  - comparison of the values of the status signals of the plural time series at the current time with the values of the status signals of the plural time series at the preceding time, and
  - production of a data packet for transmission only when at least one of the status signals of the plural time series is a changed status signal in which its value at the current time differs from its value at the preceding time, the data packet including, in a predetermined order, the following contents: the current value of the changed status signal, the current values of the status signals of the other time series of the group which contains the changed status signal, a unique identifier identifying that group, and a timestamp providing the current time; and
- wherein the central monitoring unit is further configured to transmit each produced data packet to the ground-side database, which records the contents of each transmitted data packet at predefined locations in the database according to their predetermined order.

[0015] Thus the system of the third aspect implements the method of the first aspect. Accordingly, in the system of the third aspect, preferably the status signals of the time series of each group are functionally related such that at any time interval when the value of the status signal of one time series of a given group changes, the values of the status signals of the other time series of the given group are also expected to change

[0016] In a fourth aspect, the present invention provides an on-board system for communicating condition monitoring data from a train to a ground-side database, the on-board system having:

plural monitoring sensors configured to repeatedly collect sensor readings from respective on-board equipment items of the train; and

a central monitoring unit configured to receive the sensor readings and thereby form plural time series for each of the on-board equipment items, each time series being values of a status signal equal to or derived from the sensor readings of the respective on-board equipment item and spaced at a given time interval;

wherein the central monitoring unit is further configured to perform on each time interval:

comparison of the values of the status signals of the plural time series at the current time with the values of the status signals of the plural time series at the preceding time, and

production of a data packet for transmission only when at least one of the status signals of the plural time series is a changed status signal in which its value at the current time differs from its value at the preceding time, the data packet including, in a predetermined order, the following contents: the current value of the changed status signal, the current values of the status signals of the other time series generated for the on-board equipment item from which the changed status signal derives, a unique identifier identifying that on-board equipment item, and a timestamp providing the current time; and

wherein the central monitoring unit is further configured to transmit each produced data packet to the ground-side database, which records the contents of each transmitted data packet at predefined locations in the database according to their predetermined order.

[0017] Thus the system of the fourth aspect implements the method of the second aspect. Accordingly, in the system of the fourth aspect, preferably the produced data packet includes only one unique identifier identifying the on-board equipment item.

[0018] In a fifth aspect, the present invention provides a conditioning monitoring system including the on-board system of the third or fourth aspect, and the ground-side database which records the contents of each transmitted data packet at predefined locations in the database according to their predetermined order.

[0019] In a sixth aspect, the present invention provides a train fitted with the on-board system of the third or fourth aspect

[0020] Optional features of the invention will now be set out. These are applicable singly or in any combination with any aspect of the invention unless otherwise stated.

[0021] The on-board equipment items may include: air systems, doors of the train, power generator units, air conditioning units of the train (which units may have any one or more heating, cooling and/or ventilation functions), battery systems, current collector equipment, driver cab controls, brake units of the train, traction and power equipment of the train, signalling and safety systems, vehicle controls (such as circuit breaker relays), water and toilet systems, communication and information systems (such as passenger information systems, digital voice announcement systems, seat reservation systems), fire and emergency systems, and/or bogies of the train.

[0022] In particular, when the on-board equipment items are doors of the train, the sensor readings can be readings from monitoring units which monitor the operation of the doors. The plural time series can thus include values of respective status signals for: door completely closed, door completely opened, door in process of opening, and door in process of closing. For example, the plural time series can thus be values of respective status signals for: door released for passenger operation thereof, door completely closed, door completely opened, door in process of opening, and door in process of closing. In the context of the method of the first aspect, there can, therefore, be a respective group for each time series. However, another option is for there to be a first group for the door completely closed time series and the door in process of opening time series, and a second group for the door completely opened time series and the door in process of closing time series. Yet another option is for there to be a first group for the door completely closed time series and the door in process of closing time series, and a second group for the door completely opened time series and the door in process of opening time series. With either option, there can be another group for the door released time series.

[0023] The changed status signal corresponds to a changed sensor reading from the respective on-board equipment item. Thus, while acknowledging that the collecting of the sensor readings is not in general occur instantaneous, the current time can effectively be the time at which the corresponding sensor reading changes.

[0024] The sensor readings may be repeatedly collected at a given sensing frequency from the on-board equipment items of the train. The time interval spacing the status signal values of each time series may then correspond to the sensing frequency.

[0025] The produced data packet may include only the current value of the changed status signal, the current values of the status signals of the other time series, the unique identifier, and the timestamp.

[0026] Brief Description of the Drawings

[0027] Embodiments of the invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 shows schematically a conditioning monitoring system;

Figure 2 shows time series of the values of status signals obtained from a monitoring unit sensing a typical train door operation;

Figure 3A-C shows respective examples of values for the status signals produced by the monitoring units of three doors of the train;

Figure 4 shows a data packet structure according to a first comparative example communication method;

Figure 5 shows a data packet structure according to a second comparative example communication method;

Figure 6 shows a data packet structure according to a third comparative example communication method;

Figure 7 shows a sequence of data packets according to the third comparative example communication method;

Figure 8A-C shows respective sequences of data packets according to a first communication method of the invention;

Figure 9A-E shows respective sequences of data packets according to a second communication method of the invention;

Figure 10A-C shows respective sequences of data packets according to a variant of the second communication method of the invention;

Figure 11A-C shows respective sequences of data packets according to a further variant of the second communication method of the invention; and

Figure 12 shows time series of the values of status signals obtained from a monitoring unit sensing a train heating ventilation and air-conditioning unit operation;

Detailed Description and Further Optional Features

[0028] Figure 1 shows schematically a train conditioning monitoring (CM) system. The system is in four parts.

[0029] The first part is monitoring equipment on the train in the form multiple sensors/monitoring units (MU), which repeatedly take readings from equipment items of the train. These readings are collected in a Central Monitoring Unit (CMU) and are used for train operation. The CMU makes health assessments based on the sensor readings and informs the driver/operator about on-going issues on the vehicle. The MUs can send raw measurements (typically voltage values) to the CMU for conversion at the CMU into status signal values (typically binary 0s or 1s), or the MUs can generate such status signal values themselves (i.e. the MUs' readings are in the form status signal values) for sending to the CMU. Either way, for each MU a respective time series is formed at the CMU, the time series being the values (spaced at a given time interval) of the status signal which is equal to or is derived from that MU's sensor readings.

[0030] The sensor readings of the MUs are collected at frequencies which may be of the order of 1-10Hz or higher, since their primary usage is to help train operation and to inform the driver/operator about on-going issues. The time interval of each status signal time series typically therefore reflects this collection frequency.

[0031] The second part of the CM system is a communication sub-system between the CMU and a ground-side database. The communication sub-system can be by manual download, but more typically is by transmission of data using wireless communication such as 3G and/or WiFi enabling near real-time data transfer.

[0032] The third part of the CM system is a Database Server (DS) which contains the aforementioned ground-side database in which all necessary data, including raw sensor readings, health assessments and status signal values are stored.

[0033] The fourth part of the CM system is an Application sub-system, in which applications use the data for various different purposes, such as real-time diagnostics, statistics, long-term trend analysis, prognostics, etc. The results generated by these ground-side applications are stored in the DS for future use.

[0034] To understand how data travels within the CM system, we use a door system example. The CMU collects the following status signals from a respective MU of each door of the train:

1) Door Released signal (DRS): This signal becomes "True" (i.e. "1") when the driver releases the doors. In the released state passengers are free to open the door using the door open button located on or near the door, or the driver may open all the doors using his or her own control. When DRS is "False" (i.e. "0") passengers/driver have no authority to open the door. This is generally the case when train is not stationary at an authorized station.

2) Completely Closed signal (CCS): This signal is "True" if the door is completely closed. Otherwise the signal is "False".

3) Completely Opened signal (COS): This signal is "True" if the door is completely opened. Otherwise the signal is "False".

4) Opening Operation (OOS): This signal becomes "True" when the door starts opening until it is completely opened. The signal is otherwise "False".

5) Closing Operation (CLS): This signal becomes

"True" when the door starts closing until it is completely closed. The signal is otherwise "False".

[0035] Figure 2 shows the values of these status signals for a typical door operation. The values are given at regular time intervals from T1 to T31. The door is "completely closed" and "not released" at T1. At T2, the driver releases the doors, and at T3 a passenger or the driver opens the door by a door open button. After completion of the "opening operation" at T6, the door becomes "completely opened" and stays opened until T26. At this time, the driver pushes a door closed button which starts the "closing operation". At T29 the door becomes "completely closed" and at T30 the driver deactivates door release. All doors of the train follow a similar pattern in every station, with a significantly longer period being spent between stations than the period from T1 to T31.

[0036] Figure 3A-C shows respective examples of values for the status signals produced by the MUs of three doors of the train. In the example the three doors are all released, start opening and start closing at the same time. However, due to mechanical differences, Door 2 takes 400 ms longer to open and close as compared to Door 1, while Door 3 takes 600 ms longer. The interval between signals is 200 ms, and dots in-between values indicate that the values are unchanged in that time period. The complete door opening and closing cycle is performed in the period from time 12:00:00:000 to time 12:00:28:000. Five minutes later at 12:05:28:000 another cycle is shown commencing.

[0037] If all the values were transmitted by the CMU to the DS whenever they are generated, a single data packet as shown in Figure 4 could be used for the transmission at each time interval. Moreover, because in this case the packet structure would be invariant, there is no need to send signal identifiers as the DS can use a dictionary to identify which signal is in which position in the packet. The DS can insert the data from each packet into a single table of a column-based database. If time stamps are six bytes, each signal value is one byte, and UDP (user datagram protocol) is used for communication with 28 bytes, with this comparative example method the total bytes for communication in the door operation example of Figure 3 is (UDP header + Time Stamp Length + Number of Signals)*Time Frame Length = 80409 bytes, and the total bytes for storing in a column-based database is Time Stamp Length + Number of Signals)*Time Frame Length = 34461 bytes.

[0038] In general, however, there are many more MUs, such that the number of signals to be transmitted is higher and a single data packet would be too large. In this case, it is possible to adopt a second comparative example method in which smaller data packets are sent to the DS, e.g. by grouping the signals based on their source. For example one packet can be sent for each door. In this case the packet structure can be as in Figure 5.

[0039] With this second comparative example method, an identifier for each packet is needed. Also each packet has to contain the time stamp. Thus the amount of metadata increases. However, all the signal values can be readily inserted into different tables in a column-based database of the DS or they can be combined in a single table. Again assuming time stamps are six bytes, and each signal value and packet identifier is one byte, the total bytes for communication in the door operation example of Figure 3 is (UDP header + Time Stamp Length + Number of Signals + Packet Identifier Length)*Time Frame Length*Number of MUs = 246150 bytes, and the total bytes for storing in a column-based database is (Time Stamp Length + Number of Signals + Signal Identifier Length)*Time Frame Length*Number of MUs = 59076 bytes.

[0040] In both the above comparative example methods, data are transmitted at each time interval, even when no signal values have changed. This leads to the transmission of large amounts or redundant data, which can overload the communication sub-system between the CMU and the DS, and can also overload the I/O processes of the DS.

[0041] Thus another option is send data packets only when they are needed, e.g. when there is a change in a status signal, i.e. its value at the current time differs from its value at the preceding time. For example, in a third comparative example method a packet structure as shown in Figure 6 can be adopted. In the third comparative example method, a signal identifier is needed for the DS to understand which status signal is transmitted. If two bytes are needed for each signal identifier (which must now identify the MU as well as the status signal) and considering that all signals have to be all sent one by one at initialization, the total numbers of bytes needed for the three MUs in the door operation example of Figure 3 is (UDP header + Time Stamp Length + Signal Identifier Length + 1)* Number of packets = 1776 bytes for communication, and 432 bytes for storage. Figure 7 shows the data packets (including the initializations) in this comparative example. The communication cost can be reduced by about two orders of magnitude compared to the first two comparative example methods. However, using the third comparative example method, every time any signal changes, the timestamp has to be resent separately.

[0042] As signal values are transmitted only when they are changed, most of the fields of the column-based database of the DS do not receive a value from the transmitted data packet at any given time. These fields are therefore filled in with their previous value.

[0043] Although the third comparative example method is an improvement over the first and second comparative example methods, it presents a drawback in that a time stamp and signal identifier are sent for every changed status signal.

[0044] Thus in a first method of the invention, a packet structure is used which groups status signals together by the equipment item (i.e. door in the example of Figure 3) to which their MUs apply. This is similar to the proposal of the second comparative example method. In particular, the signal values are presented in a predetermined order in the packet so that the DS can use a dictionary to identify which signal is in which position in the packet. However, in the first method of the invention, the data packets are only transmitted when one of the status values in the packet is a value of a changed status signal. Thus the first method of the invention also only sends data packets when they are needed, in the manner of the third comparative example method. If none of the status signals change at one timestamp, that packet is not sent and neither is it stored. Figure 8A-C shows respective sequences of packets transmitted for the three doors of Figure 3.

[0045] Using the first method of the invention, the total numbers of bytes needed for the three MUs in the door operation example is (UDP header + Time Stamp Length + Packet Identifier Length + Number of Signals) * Number of Packets = 960 bytes for communication and 288 bytes for storage, which are even less than the third comparative example method. Moreover, the communication sub-system can work synchronously between the on-board CMU and column-based database of the DS since all the data sent from the CMU can be inserted into the database without pre or post-processing. In addition, since most unchanging status signal values are not entered into the database, I/O times can be significantly reduced. If the Application sub-system needs continuous time series values, these can be reconstructed off-line by the applications of the sub-system.

[0046] In a second method of the invention, a packet structure is used which groups the status signal together by function (e.g. all the DRS signals in the example of Figure 3), although still in a predetermined order. In this way each packet contains signals which are related in the sense that, at at least some time intervals, when the value of the signal of one of the signals changes, the values of the other signals are also expected to change. Thus, for example, if all the signals change at the same time in a packet, the total number of packets to be sent/stored can be greatly reduced. The predetermined order of the signals again allows the DS to use a dictionary to identify which signal is in which position in the packet.

[0047] Identifying signals that change together may be performed by calculating correlations and entropy between signals. However, another option is to use existing knowledge of functions and operational characteristics to determine signal groups. Thus in the example of Figure 3, five groups can be set up corresponding to DRS, CCS, OOS, COS and CLS. Figure 9A-E shows respective sequences of packets transmitted for the five functional groups.

[0048] The total numbers of bytes needed for the three MUs in the door operation example can now be reduced to 912 bytes for communication, and 240 bytes for storage, if the packet identifier is one byte. Again, the communication sub-system can work synchronously between the on-board CMU and column-based database of the DS.

[0049] As it may be necessary to reduce the number of tables in the database of the DS, group memberships can be enlarged. For example, considering that OOS becomes "true" when CCS becomes "false" (because when a door opening operation starts, the door is not completely close anymore), these two signals change at the same times at least for a part of the door operation. A similar relationship exists between CLS and COS. Therefore, instead of the four groups of Figure 9B-E and four corresponding tables in the database of the DS, it is possible to have three groups as shown in Figure 10A-C and three corresponding tables in the database. Figure 10A is a sequence of packets for a group consisting of DRS signals and is the same as Figure9A, Figure 10B is a sequence of packets for a group consisting of OOS and CCS signals, and Figure 10C is a sequence of packets for a group consisting of CLS and COS signals. The total numbers of bytes needed for the three MUs in the door operation example then becomes 808 bytes for communication and 248 bytes for storage. Although the total bytes for storage is greater than the previous 240 bytes for storage, the larger packet sizes may be more convenient and may help to reduce identifier sizes, and also the communication load is reduced (808 bytes for communication against the previous 912 bytes).

[0050] As another example, OOS becomes "false" when COS becomes "true", and thus these two signals also change at the same times at least for a part of the door operation. Further, a similar relationship exists between CLS and CCS. Therefore, instead of the three groups of Figure 10A-C and three corresponding tables in the database of the DS, it is also possible to have three different groups as shown in Figure 11A-C and three different corresponding tables in the database. Figure 11A is a sequence of packets for a group consisting of DRS signals and is the same as Figure10A, Figure 11B is a sequence of packets for a group consisting of COS and OOS signals, and Figure 11C is a sequence of packets for a group consisting of CCS and CLS signals. Like that of Figure 10A-C, the data packet structure of Figure 11A-C can reduce the amount of data for communication and storage.

[0051] Other status signals collected from train MUs can be combined by their equipment source type or their operational characteristics. As an example, Figure 12 shows time series for three status signals of two fresh air fans (FAFs) of a train Heating Ventilation and Air-Conditioning (HVAC) unit, the three signals being: operation capacity of the unit (in five levels from 0% to 100% in steps of 25%), fan 1 operation (on/off), and fan 2 operation (on/off). Each HVAC can have any number of FAFs, although two is typical in train applications. The operation capacity signal (which can be entered manually or calculated through other indications) regulates how much and with what power each FAF should operate. According to Figure 12, when operation capacity is zero both

FAFs are off, when operation capacity is 25% or 50% the FAFs work alternately for fixed times (3 minute periods in this example), and when operation capacity is 75% or 100% both FAFs are on. Note that in each operation capacity level FAFs will work with different powers which is not shown here. One option is to form a functional group for a data packet containing the status signals of both FAF operation signals and the operation capacity signal. Furthermore, there are likely to be other HVAC units in the train with synchronised operational modes whose status signals can also be allocated to the group. Alternatively, the status signals can be grouped to form data packets based on respective HVAC units.

[0052] Other possible on-board equipment item to which the methods of the invention can be applied include brake units, traction units and passenger information systems (e.g. displays)

[0053] While the invention has been described in conjunction with the exemplary embodiments described above, many equivalent modifications and variations will be apparent to those skilled in the art when given this disclosure. Accordingly, the exemplary embodiments of the invention set forth above are considered to be illustrative and not limiting. Various changes to the described embodiments may be made without departing from the spirit and scope of the invention.

Claims

1. A method of communicating on-board condition monitoring data from a train to a ground-side database, the method including:

repeatedly collecting sensor readings from respective on-board equipment items of the train;
forming plural time series for each of the on-board equipment items, each time series being values of a status signal equal to or derived from the sensor readings of the respective on-board equipment item and spaced at a given time interval, the plural time series being assigned to respective groups on the basis that the status signals of the time series of each group are functionally related such that, at at least some time intervals, when the value of the status signal of one time series of a given group changes, the values of the status signals of the other time series of the given group are also expected to change;
on each time interval:

comparing the values of the status signals of the plural time series at the current time with the values of the status signals of the plural time series at the preceding time, and producing a data packet for transmission only when at least one of the status signals of the plural time series is a changed status signal in which its value at the current time differs from its value at the preceding time, the data packet including, in a predetermined order, the following contents: the current value of the changed status signal, the current values of the status signals of the other time series of the group which contains the changed status signal, a unique identifier identifying that group, and a timestamp providing the current time;

transmitting each produced data packet to the ground-side database; and
recording the contents of each transmitted data packet at predefined locations in the database according to their predetermined order.

2. A method according to claim 1, wherein each group includes the time series of plural substantially identical on-board equipment items.

3. A method according to claim 1 or 2, wherein the status signals of the time series of each group are functionally related such that at any time interval when the value of the status signal of one time series of a given group changes, the values of the status signals of the other time series of the given group are also expected to change.

4. A method of communicating on-board condition monitoring data from a train to a ground-side database, the method including:

repeatedly collecting sensor readings from respective on-board equipment items of the train;
forming plural time series for each of the on-board equipment items, each time series being values of a status signal equal to or derived from the sensor readings of the respective on-board equipment item and spaced at a given time interval;
on each time interval:

comparing the values of the status signals of the plural time series at the current time with the values of the status signals of the plural time series at the preceding time, and producing a data packet for transmission only when at least one of the status signals of the plural time series is a changed status signal in which its value at the current time differs from its value at the preceding time, the data packet including, in a predetermined order, the following contents: the current value of the changed status signal, the current values of the status signals of the other time series generated for the on-board equipment item from which the changed status signal derives, a unique identifier identifying that on-board equipment item, and a timestamp providing the current time;

transmitting each produced data packet to the ground-side database; and
recording the contents of each transmitted data packet at predefined locations in the database according to their predetermined order.

5. A method according to claim 4, wherein the produced data packet includes only one unique identifier identifying the on-board equipment item.

6. A method according to any one of the previous claims, wherein the on-board equipment items are: air systems, doors of the train, power generator units, air conditioning units of the train, battery systems, current collector equipment, driver cab controls, brake units of the train, traction and power equipment of the train, signalling and safety systems, vehicle controls, water and toilet systems, communication and information systems, fire and emergency systems and/or bogies of the train.

7. A method according to claim 6, wherein the on-board equipment items are doors of the train, the sensor readings being readings from monitoring units which monitor the operation of the doors.

8. A method according to claim 6, wherein the plural time series include values of respective status signals for: door completely closed, door completely opened, door in process of opening, and door in process of closing.

9. A method according to claim 8, as dependent on any one of claims 1 to 3, wherein there is a respective group for each time series.

10. A method according to claim 8, as dependent on any one of claims 1 to 3, wherein there is a first group for the door completely closed time series and the door in process of opening time series, and a second group for the door completely opened time series and the door in process of closing time series.

11. A method according to claim 8, as dependent on any one of claims 1 to 3, wherein there is a first group for the door completely closed time series and the door in process of closing time series, and a second group for the door completely opened time series and the door in process of opening time series.

12. A method according to claim 10 or 11, wherein the plural time series further include values of respective status signals for door released for passenger operation thereof, and wherein there is a third group for the door released time series. 13. A method according to any one of the previous claims, wherein the sensor readings are repeatedly collected at a given sensing frequency from the on-board equipment items of the train, and the time interval spacing the status signal values of each time series corresponds to the sensing frequency.

14. An on-board system for communicating condition monitoring data from a train to a ground-side database, the on-board system having:

plural monitoring sensors configured to repeatedly collect sensor readings from respective onboard equipment items of the train; and
a central monitoring unit configured to receive the sensor readings and thereby form plural time series for each of the on-board equipment items, each time series being values of a status signal equal to or derived from the sensor readings of the respective on-board equipment item and spaced at a given time interval, the plural time series being assigned to respective groups on the basis that the status signals of the time series of each group are functionally related such that when the value of the status signal of one time series of a given group changes, the values of the status signals of the other time series of the given group are also expected to change;
wherein the central monitoring unit is further configured to perform on each time interval:

comparison of the values of the status signals of the plural time series at the current time with the values of the status signals of the plural time series at the preceding time, and
production of a data packet for transmission only when at least one of the status signals of the plural time series is a changed status signal in which its value at the current time differs from its value at the preceding time, the data packet including, in a predetermined order, the following contents: the current value of the changed status signal, the current values of the status signals of the other time series of the group which contains the changed status signal, a unique identifier identifying that group, and a timestamp providing the current time; and

wherein the central monitoring unit is further configured to transmit each produced data packet to the ground-side database, which records the contents of each transmitted data packet at predefined locations in the database according to their predetermined order.

15. An on-board system for communicating condition monitoring data from a train to a ground-side database, the on-board system having:

plural monitoring sensors configured to repeatedly collect sensor readings from respective on-board equipment items of the train; and
a central monitoring unit configured to receive the sensor readings and thereby form plural time series for each of the on-board equipment items, each time series being values of a status signal equal to or derived from the sensor readings of the respective on-board equipment item and spaced at a given time interval;
wherein the central monitoring unit is further configured to perform on each time interval:

comparison of the values of the status signals of the plural time series at the current time with the values of the status signals of the plural time series at the preceding time, and
production of a data packet for transmission only when at least one of the status signals of the plural time series is a changed status signal in which its value at the current time differs from its value at the preceding time, the data packet including, in a predetermined order, the following contents: the current value of the changed status signal, the current values of the status signals of the other time series generated for the on-board equipment item from which the changed status signal derives, a unique identifier identifying that on-board equipment item, and a timestamp providing the current time; and

wherein the central monitoring unit is further configured to transmit each produced data packet to the ground-side database, which records the contents of each transmitted data packet at predefined locations in the database according to their predetermined order.

16. A conditioning monitoring system including the on-board system of claim 14 or 15, and the ground-side database which records the contents of each transmitted data packet at predefined locations in the database according to their predetermined order.

17. A train fitted with the on-board system of claim 14 or 15.

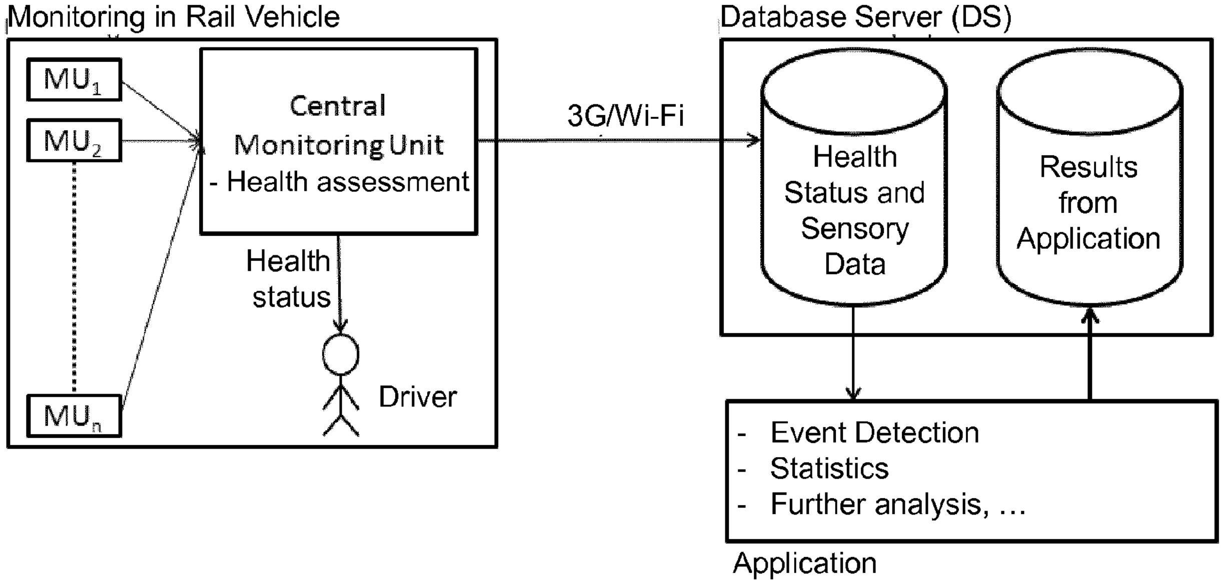
Monitoring in Rail Vehicle
MU1
MU2
MUn
Central Monitoring Unit
- Health assessment
Health status
Driver
3G/Wi-Fi
Database Server (DS)
Health Status and Sensory Data
Results from Application
- Event Detection
- Statistics
- Further analysis, ...
Application

Fig. 1

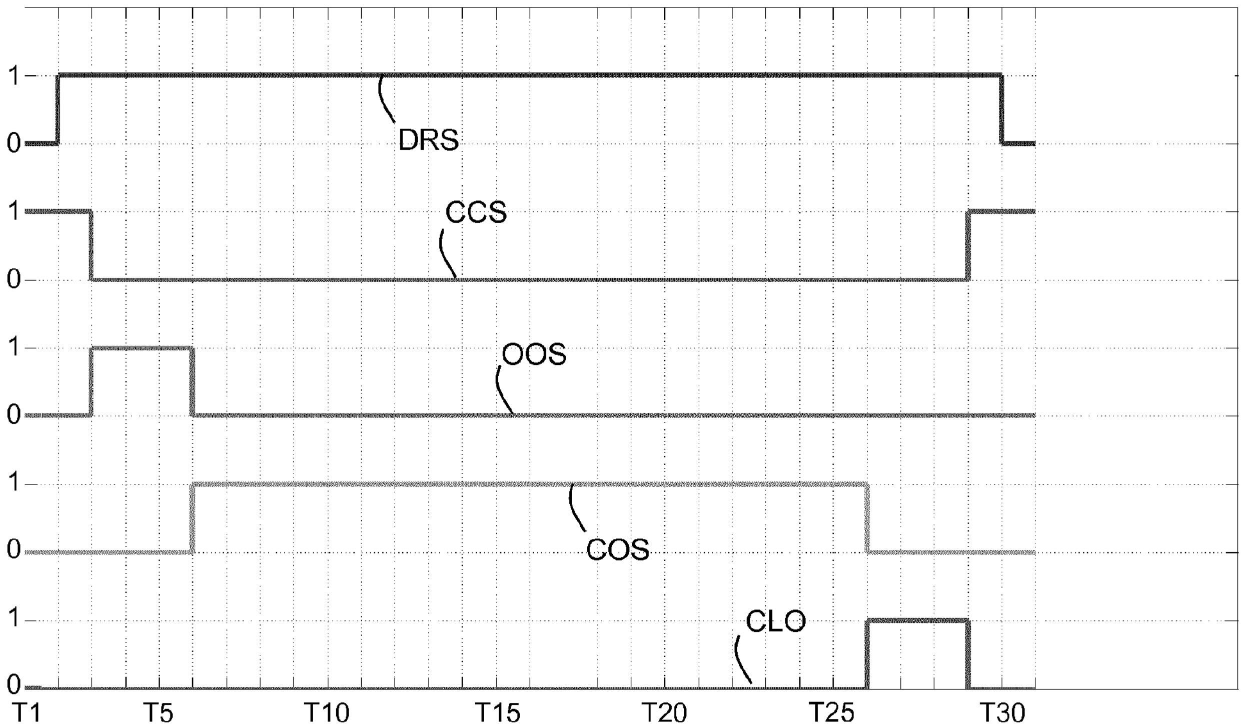
1
0
DRS
CCS
OOS
COS
CLO
T1
T5
T10
T15
T20
T25
T30

Fig. 2

Time stamp	DRS1	CCS1	OOS1	COS1	CLS1
11:59:59:800	0	1	0	0	0
12:00:00:000	1	1	0	0	0
. . .	. . .	. . .	. . .	. . .	. . .
12:00:00:800	1	1	0	0	0
12:00:01:000	1	0	1	0	0
. . .	. . .	. . .	. . .	. . .	. . .
12:00:03:800	1	0	1	0	0
12:00:04:000	1	0	0	1	0
. . .	. . .	. . .	. . .	. . .	. . .
12:00:23:800	1	0	0	1	0
12:00:24:000	1	0	0	0	1
. . .	. . .	. . .	. . .	. . .	. . .
12:00:26:800	1	0	0	0	1
12:00:27:000	1	1	0	0	0
. . .	. . .	. . .	. . .	. . .	. . .
12:00:27:800	1	1	0	0	0
12:00:28:000	0	1	0	0	0
. . .	. . .	. . .	. . .	. . .	. . .
12:05:27:800	0	1	0	0	0
12:05:28:000	1	1	0	0	0

Fig. 3A

Time stamp	DRS2	CCS2	OOS2	COS2	CLS2
11:59:59:800	0	1	0	0	0
12:00:00:000	1	1	0	0	0
. . .	. . .	. . .	. . .	. . .	. . .
12:00:00:800	1	1	0	0	0
12:00:01:000	1	0	1	0	0
. . .	. . .	. . .	. . .	. . .	. . .
12:00:04:200	1	0	1	0	0
12:00:04:400	1	0	0	1	0
. . .	. . .	. . .	. . .	. . .	. . .
12:00:23:800	1	0	0	1	0
12:00:24:000	1	0	0	0	1
. . .	. . .	. . .	. . .	. . .	. . .
12:00:27:200	1	0	0	0	1
12:00:27:400	1	1	0	0	0
. . .	. . .	. . .	. . .	. . .	. . .
12:00:27:800	1	1	0	0	0
12:00:28:000	0	1	0	0	0
. . .	. . .	. . .	. . .	. . .	. . .
12:05:27:800	0	1	0	0	0
12:05:28:000	1	1	0	0	0

Fig. 3B

Time stamp	DRS3	CCS3	OOS3	COS3	CLS3
11:59:59:800	0	1	0	0	0
12:00:00:000	1	1	0	0	0
. . .	. . .	. . .	. . .	. . .	. . .
12:00:00:800	1	1	0	0	0
12:00:01:000	1	0	1	0	0
. . .	. . .	. . .	. . .	. . .	. . .
12:00:04:400	1	0	1	0	0
12:00:04:600	1	0	0	1	0
. . .	. . .	. . .	. . .	. . .	. . .
12:00:23:800	1	0	0	1	0
12:00:24:000	1	0	0	0	1
. . .	. . .	. . .	. . .	. . .	. . .
12:00:27:400	1	0	0	0	1
12:00:27:600	1	1	0	0	0
. . .	. . .	. . .	. . .	. . .	. . .
12:00:27:800	1	1	0	0	0
12:00:28:000	0	1	0	0	0
. . .	. . .	. . .	. . .	. . .	. . .
12:05:27:800	0	1	0	0	0
12:05:28:000	1	1	0	0	0

Fig. 3C

Time Stamp	DRS1	CCS1	OOS1	COS1	CLS1	DRS2	CCS2	OOS2	COS2	CLS2	DRS3	CCS3	OOS3	COS3	CLS3

Fig. 4

Packet Identifier (Source MU)	Time Stamp	DRS	CCS	OOS	COS	CLS

Fig. 5

Signal Identifier	Time Stamp	Value

Fig. 6

Signal Identifier	Time Stamp	Value
DRS1	11:59:59:800	0
CCS1	11:59:59:800	1
OOS1	11:59:59:800	0
COS1	11:59:59:800	0
CLS1	11:59:59:800	0
DRS2	11:59:59:800	0
CCS2	11:59:59:800	1
OOS2	11:59:59:800	0
COS2	11:59:59:800	0
CLS2	11:59:59:800	0
DRS3	11:59:59:800	0
CCS3	11:59:59:800	1
OOS3	11:59:59:800	0
COS3	11:59:59:800	0
CLS3	11:59:59:800	0
DRS1	12:00:00:000	1
DRS2	12:00:00:000	1
DRS3	12:00:00:000	1
CCS1	12:00:01:000	0
CCS2	12:00:01:000	0
CCS3	12:00:01:000	0
OOS1	12:00:01:000	1
OOS2	12:00:01:000	1
OOS3	12:00:01:000	1
OOS1	12:00:04:000	0
COS1	12:00:04:000	1
OOS2	12:00:04:400	0
COS2	12:00:04:400	1
OOS3	12:00:04:600	0
COS3	12:00:04:600	1
COS1	12:00:24:400	0
CLS1	12:00:24:400	1
COS2	12:00:24:400	0
CLS2	12:00:24:400	1
COS3	12:00:24:400	0
CLS3	12:00:24:400	1
CCS1	12:00:27:000	1
CLS1	12:00:27:000	0
CCS2	12:00:27:400	1
CLS2	12:00:27:400	0
CCS3	12:00:27:600	1
CLS3	12:00:27:600	0
DRS1	12:00:28:000	0
DRS2	12:00:28:000	0
DRS3	12:00:28:000	0
DRS1	12:05:28:000	1
DRS2	12:05:28:000	1
DRS3	12:05:28:000	1

Fig. 7

A

Packet Identifier	Time stamp	DRS1	CCS1	OOS1	COS1	CLS1
PID1_1	11:59:59:800	0	1	0	0	0
PID1_1	12:00:00:000	1	1	0	0	0
PID1_1	12:00:01:000	1	0	1	0	0
PID1_1	12:00:04:000	1	0	0	1	0
PID1_1	12:00:24:000	1	0	0	0	1
PID1_1	12:00:27:000	1	1	0	0	0
PID1_1	12:00:28:000	0	1	0	0	0
PID1_1	12:05:28:000	1	1	0	0	0

B

Packet Identifier	Time stamp	DRS2	CCS2	OOS2	COS2	CLS2
PID1_2	11:59:59:800	0	1	0	0	0
PID1_2	12:00:00:000	1	1	0	0	0
PID1_2	12:00:01:000	1	0	1	0	0
PID1_2	12:00:04:400	1	0	0	1	0
PID1_2	12:00:24:000	1	0	0	0	1
PID1_2	12:00:27:400	1	1	0	0	0
PID1_2	12:00:28:000	0	1	0	0	0
PID1_2	12:05:28:000	1	1	0	0	0

C

Packet Identifier	Time stamp	DRS3	CCS3	OOS3	COS3	CLS3
PID1_3	11:59:59:800	0	1	0	0	0
PID1_3	12:00:00:000	1	1	0	0	0
PID1_3	12:00:01:000	1	0	1	0	0
PID1_3	12:00:04:600	1	0	0	1	0
PID1_3	12:00:24:000	1	0	0	0	1
PID1_3	12:00:27:600	1	1	0	0	0
PID1_3	12:00:28:000	0	1	0	0	0
PID1_3	12:05:28:000	1	1	0	0	0

Fig. 8

A

Packet Identifier	Time Stamp	DRS1	DRS2	DRS3
PID2_1	11:59:59:800	0	0	0
PID2_1	12:00:00:000	1	1	1
PID2_1	12:00:28:000	0	0	0
PID2_1	12:05:28:000	1	1	1

B

Packet Identifier	Time Stamp	CCS1	CCS2	CCS3
PID2_2	11:59:59:800	1	1	1
PID2_2	12:00:01:000	0	0	0
PID2_2	12:00:27:000	1	0	0
PID2_2	12:00:27:400	1	1	0
PID2_2	12:00:27:600	1	1	1

C

Packet Identifier	Time Stamp	OOS1	OOS2	OOS3
PID2_3	11:59:59:800	0	0	0
PID2_3	12:00:01:000	1	1	1
PID2_3	12:00:04:000	0	1	1
PID2_3	12:00:04:400	0	0	1
PID2_3	12:00:04:600	0	0	0

D

Packet Identifier	Time Stamp	COS1	COS2	COS3
PID2_4	11:59:59:800	0	0	0
PID2_4	12:00:04:000	1	0	0
PID2_4	12:00:04:400	1	1	0
PID2_4	12:00:04:600	1	1	1
PID2_4	12:00:24:000	0	0	0

E

Packet Identifier	Time Stamp	CLS1	CLS2	CLS3
PID2_5	11:59:59:800	0	0	0
PID2_5	12:00:24:000	1	1	1
PID2_5	12:00:27:000	0	1	1
PID2_5	12:00:27:400	0	0	1
PID2_5	12:00:27:600	0	0	0

Fig. 9

A

Packet Identifier	Time Stamp	DRS1	DRS2	DRS3
PID2_1	11:59:59:800	0	0	0
PID2_1	12:00:00:000	1	1	1
PID2_1	12:00:28:000	0	0	0
PID2_1	12:05:28:000	1	1	1

B

Packet Identifier	Time Stamp	CCS1	CCS2	CCS3	OOS1	OOS2	OOS3
PID3_1	11:59:59:800	1	1	1	0	0	0
PID3_1	12:00:01:000	0	0	0	1	1	1
PID3_1	12:00:04:000	0	0	0	0	1	1
PID3_1	12:00:04:400	0	0	0	0	0	1
PID3_1	12:00:04:600	0	0	0	0	0	0
PID3_1	12:00:27:000	1	0	0	0	0	0
PID3_1	12:00:27:400	1	1	0	0	0	0
PID3_1	12:00:27:600	1	1	1	0	0	0

C

Packet Identifier	Time Stamp	COS1	COS2	COS3	CLS1	CLS2	CLS3
PID3_2	11:59:59:800	0	0	0	0	0	0
PID3_2	12:00:04:000	1	0	0	0	0	0
PID3_2	12:00:04:400	1	1	0	0	0	0
PID3_2	12:00:04:600	1	1	1	0	0	0
PID3_2	12:00:24:000	0	0	0	1	1	1
PID3_2	12:00:27:000	0	0	0	0	1	1
PID3_2	12:00:27:400	0	0	0	0	0	1
PID3_2	12:00:27:600	0	0	0	0	0	0

Fig. 10

A

Packet Identifier	Time Stamp	DRS1	DRS2	DRS3
PID2_1	11:59:59:800	0	0	0
PID2_1	12:00:00:000	1	1	1
PID2_1	12:00:28:000	0	0	0
PID2_1	12:05:28:000	1	1	1

B

Packet Identifier	Time Stamp	COS1	COS2	COS3	OOS1	OOS2	OOS3
PID3_1	11:59:59:800	0	0	0	0	0	0
PID3_1	12:00:01:000	0	0	0	1	1	1
PID3_1	12:00:04:000	1	0	0	0	1	1
PID3_1	12:00:04:400	1	1	0	0	0	1
PID3_1	12:00:04:600	1	1	1	0	0	0
PID3_1	12:00:24:400	0	0	0	0	0	0

C

Packet Identifier	Time Stamp	CCS1	CCS2	CCS3	CLS1	CLS2	CLS3
PID3_2	11:59:59:800	1	1	1	0	0	0
PID3_2	12:00:04:000	0	0	0	0	0	0
PID3_2	12:00:24:400	0	0	0	1	1	1
PID3_2	12:00:27:000	1	0	0	0	1	1
PID3_2	12:00:27:400	1	1	0	0	0	1
PID3_2	12:00:27:600	1	1	1	0	0	0

Fig. 11

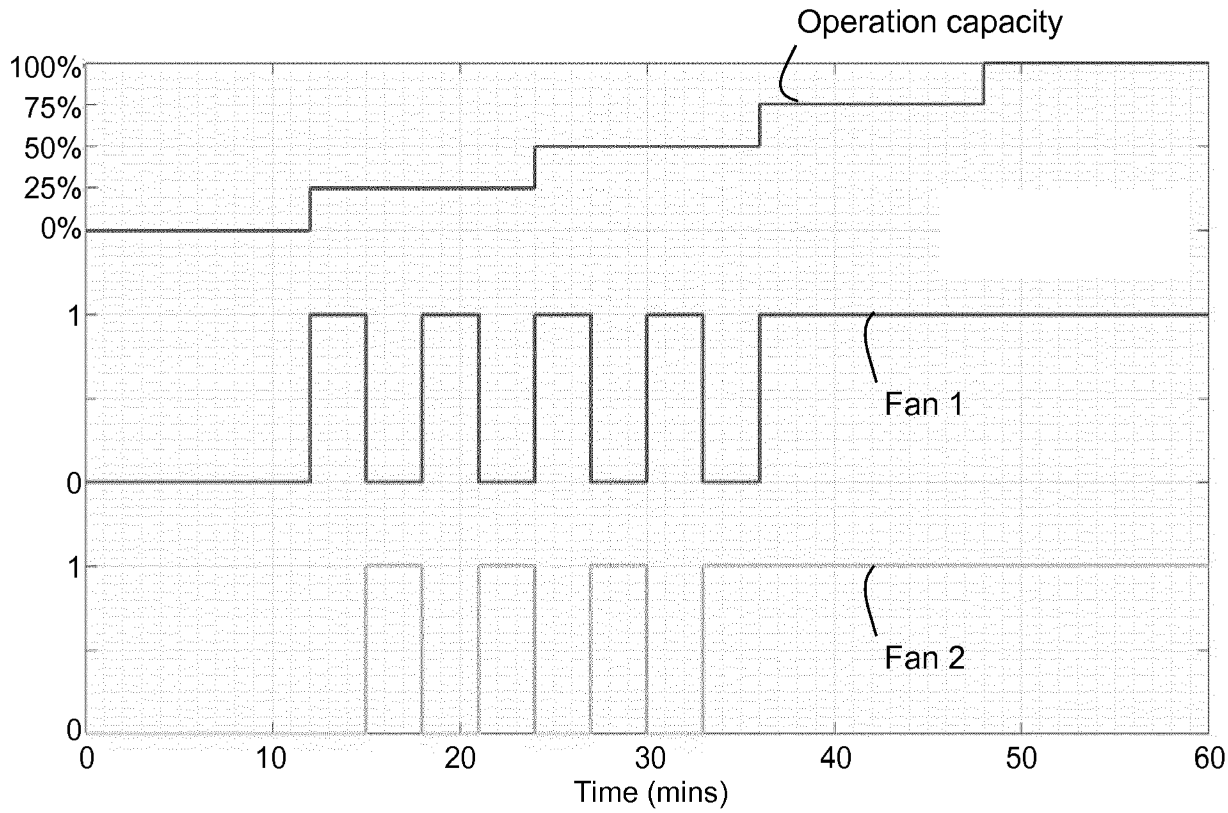
Operation capacity
100%
75%
50%
25%
0%
1
0
1
0
Fan 1
Fan 2
0
10
20
30
40
50
60
Time (mins)

Fig. 12

Europäisches Patentamt
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EUROPEAN SEARCH REPORT

Application Number
EP 18 15 5992

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X A	GB 2 510 561 A (INSIGHT DESIGN SERVICES LTD [IE]) 13 August 2014 (2014-08-13) * abstract; figures 1,3,4 * * page 3, lines 5-27 * * page 5, line 23 - page 10, line 17 * * page 11, lines 7-23 * * page 13, line 30 - page 14, line 30 * -----	4,6,7, 13,15-17 1-3,5, 8-12,14	INV. B61L15/00 B61L27/00
A	US 2002/049520 A1 (MAYS WESLEY M [US]) 25 April 2002 (2002-04-25) * abstract; figures 1-3 * * paragraphs [0003] - [0007] * * paragraphs [0014] - [0025] * -----	1-17	
A	SZALAPSKI TOMMY ET AL: "Energy efficient distributed grouping and scaling for real-time data compression in sensor networks", 2014 IEEE 33RD INTERNATIONAL PERFORMANCE COMPUTING AND COMMUNICATIONS CONFERENCE (IPCCC), IEEE, 5 December 2014 (2014-12-05), pages 1-9, XP032725855, DOI: 10.1109/PCCC.2014.7017073 [retrieved on 2015-01-20] * the whole document * -----	1-17	TECHNICAL FIELDS SEARCHED (IPC) B61L
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	25 July 2018	Robinson, Victoria

CATEGORY OF CITED DOCUMENTS

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GB 2510561	A	13-08-2014	NONE	
US 2002049520	A1	25-04-2002	NONE	

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