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METHOD FOR ESTABLISHING A PRIVATE MOBILE RADIO LINK FOR A MEASUREMENT SYSTEM

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Reference to related applications

The present application claims the priority of German patent application No.

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10 2023 206 301.8, filed on July 3, 2023, which is incorporated in its entirety by reference into this document.

Background

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Machines, systems, devices, or sensors that can be connected to the Internet via a radio connection in accordance with the Internet of Things are typically configured by the manufacturer so that they can be connected wirelessly to the Internet via a SIM card based on a mobile phone contract.

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Disclosure of the invention

If a device such as a machine, production equipment, or sensor is equipped with a SIM card at the time of manufacture, it may be possible to establish a poor or no connection to the mobile network selected in accordance with the mobile phone contract at the device's location. Alternatively, another mobile network may offer mobile connections at the device's location, which could provide a better connection to the Internet.

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According to aspects of the invention, a method for establishing an operational mobile communications connection, a measuring system, a computer program, and a machine-readable storage medium are proposed in accordance with the features of the independent

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claim. Advantageous embodiments are the subject of the dependent claims and the following description.

Throughout this description of the invention, the sequence of process steps is presented in such a way that the process is easy to follow. However, those skilled in the art will recognize that many of the process steps can also be performed in a different order and still lead to the same result. In this sense, the order of the process steps can be changed accordingly and is thus also disclosed.

According to an aspect of the invention, a method for establishing a mobile radio connection for wireless data transmission from a measuring system to a data receiver, wherein the method comprises the following steps:

In one step, a plurality of mobile radio connections offered in an environment of the measuring system are detected. In a further step, at least some of the plurality of offered mobile radio connections are characterized by determining technical operational criteria of the respective mobile radio connection and/or by querying economic operational criteria of the respective mobile radio connection. In a further step, the operational mobile radio connection is determined based on the characterization of at least part of the plurality of mobile radio connections offered. In a further step, the operational mobile radio connection is established from the measuring system to the data receiver by means of an operator profile of the operational mobile radio connection.

The measuring system can be a sensor system or any device that is set up to transmit data wirelessly to a data receiver.

The operational mobile radio connection can be a mobile radio connection that is configured to transmit the data from the measuring system wirelessly to the data receiver. The data receiver can be equipped with a storage unit to store the data from the measuring system and make it available for further evaluation. The data receiver can be a user of the measuring system and/or a provider of the measuring system. The mobile radio connections whose electromagnetic radiation can be detected by the measuring system can be offered in the vicinity of the measuring system.

The operator profile may include operator data relating to a mobile subscription, including the operator's access data and possibly SIM-based applications from the operator or third parties. The secure element of an embedded subscriber identification module (eSIM) solution is an embedded universal integrated circuit card (eUICC), which can store multiple operator profiles. Operator profiles can be downloaded remotely and wirelessly to an eUICC.

An eSIM card or iSIM card can be described as a SIM card with a rewritable operator profile, enabling a change of mobile operator or mobile connection without physically replacing the SIM card.

In other words, the measuring system can be set up and configured at a location in the vicinity of the measuring system to scan and/or determine mobile connections that are particularly suitable for wireless data transmission from the measuring system to the data receiver. The measuring system can also be configured and set up to book and/or select and/or activate the operator profile and/or a suitable mobile phone contract from an associated provider of the particularly suitable mobile phone connection.

Advantageously, the method can be used to establish the most suitable mobile radio connection for wireless data transmission, which makes it possible to establish the most suitable operational mobile radio connection at a location where the measuring system is used, even if a different mobile radio connection and/or a plurality of other mobile radio connections for wireless data transmission by the measuring system were preconfigured during the manufacture of the measuring system. The other mobile radio connection(s) can be used to establish a connection in order to carry out the method based on a first connection. This allows a mobile radio connection to be established as an operational mobile radio connection, which provides a mobile radio connection at the location where the measuring system is used and/or provides an improved connection, particularly with regard to data transmission and/or signal strength.

When the measuring system is activated for the first time at a location of use, the measuring system can detect local mobile networks by, for example, scanning the mobile networks and/or establishing a connection to the local mobile networks. For example, the local mobile

network can provide the operating mobile connection whose signal strength is maximum at the location of use. Using a mobile communications connection based on a standard mobile communications contract preinstalled on the measuring system, the measuring system can be set up and configured to establish the most suitable mobile communications connection by transferring the corresponding operator profile and/or mobile communications contract to the measuring system and activating it. Alternatively or additionally, the measuring system can be set up so that the corresponding operator profile and/or mobile phone contract is loaded and activated locally via an operating tool of the measuring system.

According to an aspect, the operator profile for establishing the operational mobile connection is provided to the measuring system by means of an established initial mobile connection. Alternatively or additionally, the operator profile is provided from a memory area of the measuring system for activating the operator profile to establish the operational mobile connection.

In other words, the measuring system can be configured to store a plurality of operator profiles and/or a plurality of identifiers and/or a plurality of mobile phone contracts in order to select and/or activate and/or establish corresponding mobile phone connections. Mobile phone connections that were previously used for wireless data transmission can be deactivated and/or "returned" to a server. By "returning" it to the server, the now free contract can be assigned to another device or measurement system. Alternatively or additionally, "returning" it to the server can free up storage space in the measurement system for storing an alternative and/or better contract. This is because storage space in the measurement system is typically limited. Alternatively or additionally, the measurement system can be configured and set up to store a large number of passive operator profiles and/or a large number of passive identifiers and/or a large number of passive mobile phone contracts that are set up to establish a mobile phone connection as soon as a certain amount of data has been transferred.

A server of the provider of the measurement system may be configured to establish a mobile communications connection with the measurement system in order to provide the measurement system with the plurality of operator profiles and/or the plurality of identifiers and/or the plurality of mobile communications contracts.

The measuring system may be configured and set up to request the operator profile for the operational mobile radio connection for provision of the operator profile from a mobile radio operator.

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The measuring system may be configured and set up so that operator profiles are provided to the measuring system via the start mobile radio connection, whereby a start operator profile for establishing the start mobile radio connection is stored in the measuring system.

- 10 To establish the respective mobile radio connection, a user of the measuring system may have concluded a usage contract with the service provider of the respective mobile radio connection.

According to an aspect, it is proposed that the determination of the operational mobile radio connection be additionally based on a characterization of the established operational mobile radio connection and/or the established initial mobile radio connection, using the technical operational criteria and/or the economic operational criteria. The operational mobile connection can be updated according to the characterization of the established operational mobile connection and/or the characterization of the established initial mobile connection and at least part of the plurality of mobile connections offered.

According to an aspect, the technical operating criteria for characterizing the respective mobile radio connection may include: a characteristic signal strength of the respective mobile radio connection (RSSI: Received Signal Strength Indicator); and/or a characteristic availability of data transmission via the respective mobile radio connection (); and/or a characteristic maximum transmission speed via the respective mobile radio connection; and/or a characteristic quality of data transmission via the respective mobile radio connection; and/or a characteristic signal-to-noise ratio of the respective mobile radio connection; and/or a characteristic latency time of the respective mobile radio connection and/or a transmission technology of the respective mobile radio connection; and/or available functionalities of the transmission technology, such as an Extended Discontinuous Reception (eDRX) power-saving technology, of the respective mobile radio connection.

The respective mobile connection may be based on a variety of mobile technologies, such as 2G, 3G, 4G, LTE, NB-IoT, LTE-M1, 5G, 6G, etc., and the measurement system may be set up to perform the method based on at least some of the variety of mobile technologies. This means that the detection and characterization of the respective mobile communications connections can relate to different mobile communications providers as well as different mobile communications technologies in order to establish the most suitable mobile communications connection as the operating mobile communications connection for wireless data transmission. In particular, the mobile communications connection that has the highest possible signal strength at the location of the measurement system can be determined.

According to an aspect, the respective mobile communications connections can be scanned with regard to the technical operating criteria in order to characterize them. Alternatively or additionally, the respective mobile communications connections can be established with the measuring system in order to characterize them.

In this case, the respective mobile radio connection can be characterized by means of roaming based on the start mobile radio connection. Alternatively or additionally, the mobile radio connection can be characterized by means of the respective active and/or established operating mobile radio connection.

According to an aspect, the economic operating criteria for characterizing the respective mobile radio channel may include: costs per amount of data transmitted using the respective mobile radio channel; and/or costs per duration of data transmission using the respective mobile radio channel; and/or flat-rate costs for data transmission using the respective mobile radio channel.

According to an aspect, the technical operating criteria for characterizing the respective mobile radio connection can be determined by means of a determination module of the measuring system; and/or the economic operating criteria for characterizing the respective mobile radio connection can be determined by means of a query to an external database using the start mobile radio connection and/or the operating mobile radio connection. The external database may be a database in the cloud that is signal-coupled to the Internet via a server, whereby data for the economic operating criteria may be stored in the database.

According to an aspect, the determination module may comprise a determination storage module for determining and/or storing the signal strength and/or the signal-to-noise ratio and/or the latency and/or the availability of the respective mobile radio connection as a time sequence in order to determine from the respective time sequence the characteristic signal strength of the respective mobile radio connection; and/or the characteristic availability of data transmission via the respective mobile radio connection; and/or the characteristic maximum transmission speed via the respective mobile radio connection; and/or the characteristic quality of data transmission via the respective mobile radio connection; and/or the characteristic signal-to-noise ratio of the respective mobile radio connection; and/or the characteristic latency of the respective mobile radio connection; and/or a transmission technology of the respective mobile radio connection; and/or available functionalities of the transmission technology of the respective mobile radio connection.

According to an aspect, the determination of the operating mobile radio connection can be based on an overall evaluation of the operating criteria, wherein the overall evaluation comprises individually weighted technical operating criteria and/or individually weighted economic operating criteria, respectively.

The sum of the weights of the technical operating criteria may be greater than the sum of the weights of the economic operating criteria. In particular, the signal strength of the respective mobile radio connection may be weighted more heavily than other economic operating criteria.

According to an aspect, the measurement system may be configured and set up to adapt the individual weights of the overall evaluation to interruptions in data transmission, and/or fluctuations in operating criteria, and/or changes in operating criteria, whereby the interruptions in data transmission are determined by means of the determination module in order to achieve data transmission that is as uninterrupted as possible.

The measurement system can be set up and configured to determine a cause for at least part of the interruption in data transmission and to adjust individual weights of the overall evaluation based on the determined cause of the interruption in data transmission. For

example, the weight of the technical operating criterion signal strength of the respective mobile radio connection can be reduced if a number of interruptions in data transmission exceeds a threshold value.

- 5 For this purpose, the measuring system can be configured and set up to store interruptions in data transmission and, in particular, to determine the causes of the interruptions. The measuring system can also be configured and set up to track interruptions and, in particular, to report the occurrence of a respective interruption of the respective mobile connection to the external database described above.

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The measurement system can be configured and set up to determine the individual weights of the overall evaluation using artificial intelligence methods and/or machine learning methods.

- 15 The measurement system may be configured to start a query of the external database when determining the operational mobile connection in order to retrieve a measure of tracked interruptions from other measurement systems in the vicinity of the measurement system in order to determine the operational mobile connection.

- 20 According to an aspect, the respective operator profile can be stored using an embedded subscriber identity module; and/or a subscriber identity module; and/or a soft subscriber identity module.

- 25 The measuring system can be set up to store the respective operator profile by means of the embedded subscriber identity module and/or the subscriber identity module and/or the soft subscriber identity module.

- 30 The electronic subscriber identity module and/or the subscriber identity module and/or the soft subscriber identity module can have the start operator profile, in particular already during commissioning.

The embedded subscriber identity module (eSIM) can be based on an "embedded universal integrated circuit card (eUICC)" that is permanently integrated into the measuring system.

Alternatively or additionally, the subscriber identity module can be emulated as a soft SIM in the form of software. The eSIM and/or the soft SIM can be set up to have a plurality of mobile phone contracts and/or operator profiles, which can be exchanged both via an operating tool for the measuring system and via the mobile phone connection.

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According to an aspect, it is proposed that the measuring system be configured and set up to determine the respective location of the measuring system using the determination module and to store this together with the last used operational mobile connection in order to establish the last used operational mobile connection for wireless data transmission from the measuring system to the data receiver when the measuring system is used again at the respective location.

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The measuring system can be set up to store the mobile communications connections offered at the respective location, in particular together with the respective signal strength, and in particular to transfer them to a database in the cloud so that other measuring systems can use this information to determine the operating mobile communications connection. To determine the respective location, a Bluetooth connection and/or a WLAN connection available there or other location-related features, such as an identifier of a mobile phone mast and/or recognition of a provider of the respective mobile phone connection and/or a country identifier and/or information about the coverage of a mobile phone mast of the respective mobile phone connection, can be used. can be used to determine the respective location. The measuring device can be configured and/or set up, in particular by means of the determination module, to determine the respective location by means of GNSS (GPS, GLONASS, etc.). Alternatively or additionally, the measuring device can be configured and/or set up, in particular by means of the determination module, to be coupled with another sensor and/or device based on a physical connection, i.e., wired, for example by means of a plug-in module, in order to determine the location for selecting the operating mobile phone connection.

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The measuring system can be configured and set up to identify a location with location-related characteristics and to re-establish a stored operational mobile radio connection that was previously successfully established at the respective location as an operational mobile radio connection.

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According to an aspect, the method can be executed when the measuring system is switched on and/or can be repeated cyclically during operation of the measuring system. Alternatively or additionally, it can be executed when data transmission via a current
5 operational mobile radio connection is interrupted.

The measuring system can be set up so that a change to an operator profile for a changed mobile radio connection is carried out using a current mobile radio connection via a server and/or via an operator.

10 A measuring system is proposed which has a sensor unit for generating measurement data. In addition, the measuring system has a wireless transmission and reception unit for establishing an operational mobile radio connection, which is coupled to the sensor unit in terms of signals. In addition, the measuring system has a determination module for
15 characterizing the respective mobile radio connection based on technical operating criteria and/or economic operating criteria. In addition, the measuring system may have an electronic subscriber identity module, and the measuring system may be configured and set up to perform one of the methods described above.

The measuring system may be a sensor system and, in particular, may be signal-coupled to
20 the external database based on a mobile radio connection.

A computer program is proposed which comprises commands which, when the computer program is executed by a computer, cause the computer to execute one of the methods described above.
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With such a computer program, the method can be easily implemented in different environments and/or applications and/or platforms.

A machine-readable storage medium is proposed on which the computer program described
30 above is stored.

This allows the method to be easily implemented on different control and monitoring devices.

A use of the measuring system for acquiring sensor data in a manufacturing environment is proposed, whereby the acquired sensor data is transmitted wirelessly to a data receiver.

Examples of implementation

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Examples of embodiments of the invention are shown with reference to Figures 1 and explained in more detail below.

Figure 1 shows a method for establishing an operational mobile radio connection.

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Figure 1 outlines a flowchart of a method 100 for establishing an operational mobile radio connection. During production, the measuring system may have been configured and/or equipped with an operator profile for a start mobile radio connection, whereby the start mobile radio connection may have a minimum data volume and/or a minimum cost budget. To establish an operational mobile radio connection for wireless data transmission from a measurement system to a data receiver (), the measurement system can detect a plurality of mobile radio connections (S1) offered in the vicinity of the measurement system at a location of use. In a further step S2, at least some of the many mobile communications connections offered can be characterized by means of the measuring system by determining technical operating criteria 110 of the respective mobile communications connection and/or querying economic operating criteria 120 of the respective mobile communications connection. In a further step S3, the operational mobile radio connection can be determined based on the characterization of at least part of the multitude of mobile radio connections offered. And in a step S4, the operational mobile radio connection can be established from the measuring system to the data receiver by means of an operator profile 130, 140 of the operational mobile radio connection.

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Based on the start mobile radio connection that can be established, the operator profile for establishing the operating mobile radio connection 130 can be provided to the measuring system. Alternatively or additionally, the operator profile can be provided from a memory area of the measuring system 140 for activation to establish the operating mobile radio connection.

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This method 100 for establishing an operational mobile radio connection can either be executed when the measuring system is switched on or put into operation and/or repeated cyclically 150 during operation of the measuring system in order to run through steps S1 to S4. Alternatively or additionally, the method 100 for establishing the operational mobile radio connection can be executed in the event of an interruption in data transmission via a current operational mobile radio connection.

Claims

- 5 1. Method (100) for establishing an operational mobile radio connection for wireless data transmission from a measuring system to a data receiver, comprising:
 detecting (S1) a plurality of mobile radio connections offered in an environment of the measuring system;
 characterizing (S2) at least a portion of the plurality of offered mobile radio
10 connections by determining technical operating criteria (110) of the respective mobile radio connection and/or querying economic operating criteria (120) of the respective mobile radio connection;
 determining (S3) the operational mobile radio connection based on the characterization of at least part of the plurality of mobile radio connections offered; and
15 establishing (S4) the operational mobile radio connection from the measuring system to the data receiver by means of an operator profile (130, 140) of the operational mobile radio connection.
- 20 2. Method (100) according to claim 1, wherein the operator profile for establishing the operational mobile radio connection is provided to the measuring system by means of an established start mobile radio connection (130); and/or the operator profile is provided from a memory area of the measuring system for activating the operator profile (140) for establishing the operational mobile radio connection.
- 25 3. Method (100) according to claim 1 or 2, wherein the determination of the operational mobile radio connection is additionally based on a characterization of the established operational mobile radio connection and/or the established initial mobile radio connection, by means of the technical operational criteria (110) and/or the economic operational criteria (120); and the operational mobile radio connection is updated in
30 accordance with the characterization of the established operational mobile radio connection and/or the characterization of the established initial mobile radio connection and at least part of the plurality of mobile radio connections offered.

4. Method (100) according to one of the preceding claims, wherein the technical operating criteria (110) for characterizing the respective mobile radio connection comprise: a characteristic signal strength of the respective mobile radio connection; and/or a characteristic availability of data transmission via the respective mobile radio connection; and/or a characteristic maximum transmission speed via the respective mobile radio connection; and/or a characteristic quality of data transmission via the respective mobile radio connection; and/or a characteristic signal-to-noise ratio of the respective mobile radio connection; and/or a characteristic latency of the respective mobile radio connection and/or a transmission technology of the respective mobile radio connection; and/or available functionalities of the transmission technology of the respective mobile radio connection.

5. Method (100) according to one of the preceding claims, wherein, in order to characterize the respective mobile radio connections, the respective mobile radio connections are scanned with respect to the technical operating criteria (110); and/or, in order to characterize the respective mobile radio connections, the respective mobile radio connections are established with the measuring system.

6. Method (100) according to one of the preceding claims, wherein the economic operating criteria (120) for characterizing the respective mobile radio channel comprise: costs per amount of data transmitted via the respective mobile radio channel; and/or costs per duration of a data transmission via the respective mobile radio channel; and/or flat-rate costs for data transmissions via the respective mobile radio channel.

7. Method (100) according to one of the preceding claims, wherein the technical operating criteria (110) for characterizing the respective mobile radio connection are determined by means of a determination module of the measuring system; and/or the economic operating criteria (120) for characterizing the respective mobile radio connection are determined by means of a query to an external database using the start mobile radio connection and/or the operating mobile radio connection.

8. Method (100) according to claim 6, wherein the determination module comprises a determination storage module for determining and/or storing the signal strength and/or the signal-to-noise ratio and/or the latency and/or the availability of the respective mobile radio

connection as a time sequence in order to determine from the respective time sequence the characteristic signal strength of the respective mobile radio connection; and/or the characteristic availability of data transmission via the respective mobile radio connection; and/or the characteristic maximum transmission speed via the respective mobile radio connection; and/or the characteristic quality of data transmission via the respective mobile radio connection; and/or the characteristic signal-to-noise ratio of the respective mobile radio connection; and/or the characteristic latency time of the respective mobile radio connection; and/or a transmission technology of the respective mobile radio connection; and/or available functionalities of the transmission technology of the respective mobile radio connection.

9. Method (100) according to one of the preceding claims, wherein the determination of the operating mobile radio connection is based on an overall evaluation of the operating criteria (110, 120), wherein the overall evaluation comprises individually weighted technical operating criteria (110) and/or individually weighted economic operating criteria (120).

10. Method (100) according to claim 9, wherein the measuring system is configured and set up to adapt the individual weights of the overall evaluation of the operating criteria (110, 120) depending on interruptions of data transmissions, and/or fluctuations in operating criteria and/or changes in the operating criteria of the respective established mobile operating connection, wherein the interruptions in data transmissions are determined by means of the determination module in order to achieve data transmission that is as interruption-free as possible.

11. Method (100) according to one of the preceding claims, wherein the respective operator profile is stored by means of an electronic subscriber identity module; and/or a subscriber identity module; and/or a soft subscriber identity module.

12. Method (100) according to one of the preceding claims, wherein the method (100) according to one of claims 1 to 11 is executed when the measuring system is switched on; and/or the method (100) is repeated cyclically during operation of the measuring system; and/or the method (100) is executed when data transmission via a current operational mobile radio connection is interrupted.

13. Measuring system comprising:

a sensor unit for generating measurement data;

5 a wireless transmission and reception unit for establishing an operational mobile radio connection, which is coupled to the sensor unit in terms of signals;

a determination module for characterizing the respective mobile radio connection based on technical operating criteria (110) and/or economic operating criteria (120); and

an electronic subscriber identity module, wherein the measuring system is configured to execute a method according to one of claims 1 to 12.

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14. Computer program comprising instructions which, when executed by a computer, cause the computer to execute a method according to one of claims 1 to 12.

15. Machine-readable storage medium on which the computer program according to claim 14 is stored.

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