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(54) ACCESS CONTROL SYSTEM, PORTABLE USER DEVICE, AND METHOD OF CONTROLLING ACCESS

(57) An access control system (10) comprises a radio interface (12) configured to communicate with a portable user device (20), an electroacoustic transducer (13, 14), and a control circuit (11). The control circuit (11) is configured to selectively activate an actuator (7) in an access grant procedure based on a propagation time of the acoustic signal between the electroacoustic transducer (13, 14) and the portable user device (20).

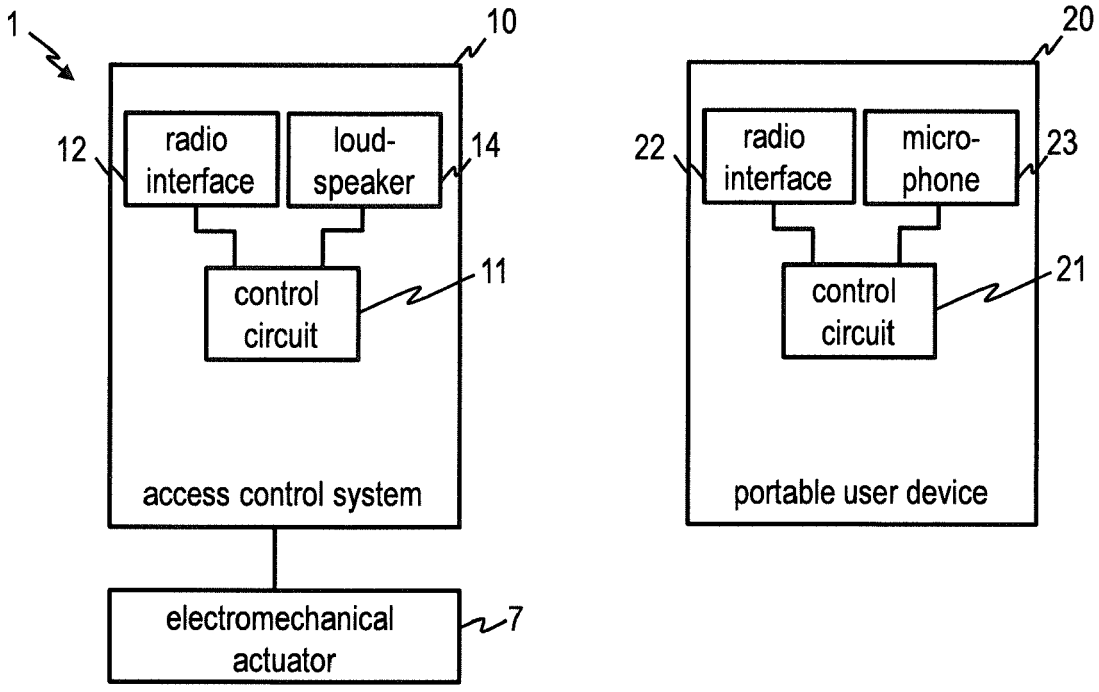


FIG. 2

EP 3 300 033 A1

Description

TECHNICAL FIELD

[0001] The present invention relates to devices, systems, and methods for controlling access. The present invention relates in particular to devices, systems and methods that are operative to employ radio signal transmission between a portable user device and a locking cylinder, a door handle unit, or another access control system to establish whether the user of the portable user device is authorized to be granted access to a delimited area, such as a building, room, or part of a room.

BACKGROUND OF THE INVENTION

[0002] Locking systems having one or several electronic locks and one or several devices that are capable of acting as electronic keys are known in the art. For illustration, active transponders, cellular phones, or other portable user devices may be used as a form of electronic key for accessing buildings, rooms, or other delimited areas. Such electronic keys may offer advantages over conventional, purely mechanical locking systems having purely mechanical keys and purely mechanical locks. The capability of modifying a configuration of a locking system and of flexibly re-assigning an access authorization, such as by enabling or disabling a certain portable user device for unlocking a given door, is but one of the advantages afforded by such systems.

[0003] A portable user device acting as an electronic key and an access control system may communicate with each other via a radio interface. Depending on the implementation of the radio interface and the locations at which different electronic door locks are arranged, a portable user device acting as an electronic key may be located within the radio transmission area of multiple electronic door locks. This may cause plural doors to be unintentionally unlocked at the same time, unless appropriate counter-measures are implemented. One way to address this issue is the use of communication techniques that have a short operation range, such as Near Field Communication (NFC). An exemplary system is disclosed in EP 2 620 919 A1.

[0004] When multiple electronic door locks are discovered by an electronic key, the electronic key may be prompted to request the user to select, via a user interface, one of the electronic door locks for unlocking. This may be time-consuming and may require a degree of user interaction that some users may consider to be tedious. Alternatively or additionally, location and directionality information may be detected to determine which door is to be unlocked. Exemplary systems that use location and direction information are disclosed in US 2016/0066254 A1, for example. The additional hardware components may add significantly to the costs of the portable user devices.

[0005] With increasing popularity of electronic locks and portable user devices acting as electronic keys, deployment and maintenance costs becomes an increasingly relevant issue. For illustration, it would be desirable to implement electronic access control systems and portable user devices acting as electronic keys using communication techniques that are available at low cost and that do not drain battery power too rapidly. While many portable user devices are provided with radio interfaces having a communication range that is on the order of or exceeds several meters, such as Bluetooth Low Energy (BLE), such communication techniques may be prone to fraudulent relaying attacks in which a radio signal transmitted by a portable user device is actively relayed to a door that the user of the portable user device did not wish to open.

SUMMARY OF THE INVENTION

[0006] In view of the above, there is a continued need for devices, systems and methods for controlling access which address at least some of the above needs. There is in particular a need for devices, systems, and methods that allow radio communication techniques having a range exceeding one or several meters to be used for electronically unlocking an area, while ensuring that the user's intent to unlock a certain area is taken into account without requiring excessive user interaction and/or the risk of fraudulent relaying attacks is mitigated.

[0007] An access control system, a portable user device, and a method as defined by the independent claims are provided. The dependent claims define embodiments.

[0008] According to embodiments of the present invention, the propagation time of an acoustic signal between an access control system and a portable user device is determined. The propagation time is indicative of whether the portable user device is located within a pre-determined distance range from the access control system. A wide variety of portable user devices, such as cellular phones, have the required hardware to detect an acoustic signal generated by the access control system and/or to generate an acoustic signal for transmission to the access control system. The verification of whether the portable user device is located within a distance range which indicates the user's intent to unlock a certain area may thereby be implemented at moderate additional cost. Moreover, the transmission of an acoustic signal between the access control system and the portable user device mitigates the risk of fraudulent relaying attacks. Even if radio signals transmitted by the portable user device are relayed to a remote area in a fraudulent manner, the propagation time and/or attenuation of audio signals between an access control system located in the remote area and the portable user device will allow the fraudulent tampering to be detected.

[0009] An access control system according to an embodiment comprises a radio interface, an electroacoustic transducer, and a control circuit. The radio interface is

configured to communicate with a portable user device. The control circuit is coupled to the radio interface and to the electroacoustic transducer. The control circuit is configured to trigger transmission of an acoustic signal between the electroacoustic transducer and the portable user device in response to a signal received from the portable user device at the radio interface. The control circuit may be configured to selectively activate an actuator in an access grant procedure based on a propagation time of the acoustic signal between the electroacoustic transducer and the portable user device.

[0010] The access control system allows proximity of the portable user device to be detected in a simple, robust, and cost-efficient manner. The access control system can thereby confirm the user's intent to be granted access by this access control system, if the propagation time indicates that the portable user device is located within a pre-determined distance range from the electroacoustic transducer of the access control system. The distance, for which the propagation time is indicative, may be used to verify the user's intent. Alternatively or additionally, the access control system may be operative to mitigate the risk of fraudulent relaying attacks. A relaying attack may be detected if the propagation time indicates that the portable user device is located outside a pre-determined distance range from the electroacoustic transducer of the access control system.

[0011] The access grant procedure may comprise a verification of the credential, e.g., by verifying that the portable user device is authorized to be granted access, before the actuator is activated. Additional verification steps may be performed. For illustration, the amplitude of the acoustic signal may be evaluated to determine whether the portable user device is located inside or outside of the area to which access is desired. The actuator may be activated only if the portable user device is located outside of the area, but not when the portable user device is located inside of this area. Unintentional unlocking of a door, for example, may be prevented if the portable user device is already in the area protected by the access control system. An amplitude threshold comparison may be performed to determine, based on the amplitude of the acoustic signal, whether the portable user device is located outside of the area protected by the access control system.

[0012] The access control system may be installed in locking cylinder, a door handle unit, or another component that is installable in a door, such as a door fitting assembly, for example.

[0013] The electroacoustic transducer may comprise a loudspeaker and/or a microphone.

[0014] The radio interface may be a Bluetooth Low Energy (BLE) interface. Battery lifetime of the access control system may be increased thereby. Further, the BLE interface allows electronic keys to be implemented at moderate cost overhead, because cellular phones and many other portable user devices that can act as electronic keys are provided with BLE interfaces. Active transponders may be equipped with a BLE interface at moderate additional costs.

[0015] The radio interface may be or may include a legacy Bluetooth interface, a Long Term Evolution (LTE) machine-to-machine (M2M) interface, a Zigbee interface, or other radio communication interfaces.

[0016] The access control system may further comprise a presence detector configured to detect presence of the portable user device next to the access control system. The presence detector allows power consumption to be further reduced by selectively activating components of the access control system only when presence of an object next to the access control system is detected. The presence detector may comprise a resonant circuit. A resonance frequency of the resonant circuit may be indicative of presence of the object.

[0017] The control circuit may be coupled to the presence detector. The control system may be configured to selectively activate the radio interface if the presence of the portable user device is detected. Battery lifetime may be increased thereby.

[0018] The radio interface may be configured to start transmission of or scanning for a BLE advertising signal when the presence of the portable user device is detected. Battery lifetime may be increased thereby.

[0019] The control circuit may be configured to control the electroacoustic transducer to generate the acoustic signal in response to the signal from the portable user device. The signal from the portable user device may be a BLE advertising signal or a signal transmitted during or after radio connection setup. The control circuit may be configured to process a confirmation signal received at the radio interface from the portable user device to determine the propagation time of the acoustic signal. The confirmation signal may include information on a time at which the portable user device received the acoustic signal, and the control circuit of the access signal may determine the propagation time based on a transmit time of the acoustic signal and the time at which the portable user device received the acoustic signal. The confirmation signal may alternatively carry information on the propagation time if the propagation time is calculated by the portable user device.

[0020] The control circuit may be configured to monitor an output signal of the electroacoustic transducer to determine at which time the acoustic signal is received from the portable user device, in response to the signal from the portable user device. The signal from the portable user device may be a BLE advertising signal or a signal transmitted during or after radio connection setup. The control circuit may determine the propagation time of the acoustic signal.

[0021] The control circuit may be configured to selectively activate the actuator if the propagation time indicates that the portable user device is located within a pre-determined range from the access control system and if the portable user device is authenticated to be entitled to access. Information identifying the portable user

device, which allows the access control system to determine whether the portable user device is authenticated to be entitled to access, and/or access code information authenticating the portable user device may be received from the portable user device at the radio interface.

[0022] The control circuit may be configured to determine, based on an amplitude of the acoustic signal, whether the portable user device is located outside or within the area to which access is controlled by the access control system. The control circuit may be configured to selectively activate the actuator if the following conditions are fulfilled cumulatively: the propagation time indicates that the portable user device is located within a pre-determined range from the access control system, the portable user device is authenticated to be entitled to access, and the portable user device is located outside of the area to which access is to be granted. If one or several of these conditions is not fulfilled, access is denied.

[0023] The electroacoustic transducer may be configured to generate and/or receive an acoustic signal which is a sound signal. The sound signal may be modulated, e.g., so as to have a time-varying frequency, amplitude, and/ duration, to facilitate discrimination of the sound signal from ambient sound.

[0024] The sound signal may comprise coded information. The coded information may be unique for the access control system at least in the locking system to which the access control system belongs and/or may depend on the portable user device that requests access. Safety may be further increased thereby. The information may be encoded in one or more of: a frequency of the acoustic signal, an amplitude of the acoustic signal, a duration of the acoustic signal, a repetition rate of the acoustic signal, and/or a time delay between repetitions of the acoustic signal.

[0025] A locking cylinder according to an embodiment may comprise the access control system according to any one of the embodiments disclosed herein. The locking cylinder may comprise a housing having a cavity in which the access control system according to an embodiment is disposed, to allow the access control system to be mounted on a door in a unitary structure.

[0026] A door handle unit according to an embodiment may comprise the access control system according to any one of the embodiments disclosed herein. The door handle unit may comprise a shell having a cavity in which the access control system according to an embodiment is disposed, to allow the access control system to be mounted on a door in a unitary structure.

[0027] A door fitting assembly according to an embodiment may comprise the access control system according to any one of the embodiments disclosed herein. The door fitting assembly may comprise a housing having a cavity in which the access control system according to an embodiment is disposed, to allow the access control system to be mounted on a door in a unitary structure.

[0028] The electromagnetic transducer of the access control system may be arranged on a side of the access control system which, in the installed state, faces towards the outside of the area to which access is controlled. The electromagnetic transducer may be arranged such that the acoustic signal is predominantly emitted to or received from a side of a door which, in the installed state, corresponds to the exterior of a building, while signals from the interior of the building are attenuated. Directional sensitivity for inside-outside-detection may be attained thereby.

[0029] A portable user device according to an embodiment comprises a radio interface configured to communicate with an access control system, an electroacoustic transducer, and a control circuit. The control circuit is coupled to the radio interface and to the electroacoustic transducer. The control circuit is configured to control the radio interface to transmit a request signal to the access control system. The control circuit is configured to monitor an output signal of the electroacoustic transducer to detect receipt of an acoustic signal from the access control system or control the electroacoustic transducer to generate an acoustic signal. The control circuit is configured to control the radio interface to transmit a confirmation signal to the access control system after receipt or transmission of the acoustic signal.

[0030] The portable user device allows proximity of the portable user device to an access control system to be detected in a simple, robust, and cost-efficient manner, based on the propagation time of an acoustic signal. The user's intent to gain access to a certain area protected by the access control system may thereby be verified. Alternatively or additionally, the acoustic signal transmission between the portable user device and the access control system allows fraudulent relaying attacks to be detected.

[0031] Inside-outside detection may be implemented such that the portable user device automatically can unlock a door only if the portable user device is located outside of the area protected by the access control system. The amplitude of the acoustic signal may be used as an indicator for whether the portable user device is located inside or outside of the area.

[0032] The electroacoustic transducer may comprise a microphone. The control circuit may be configured to monitor an output signal of the microphone to detect receipt of the acoustic signal from the access control system and to control the radio interface to transmit the confirmation signal to the access control system to confirm detection of the acoustic signal.

[0033] The confirmation signal may include information on a time at which the portable user device detected the acoustic signal from the access control system and/or information on the propagation time of the acoustic signal between the user equipment and the access control system.

[0034] The electroacoustic transducer may comprise a loudspeaker. The portable user device may be configured to generate the acoustic signal to allow the access

control system to measure the propagation time of the sound signal from the portable user device to an electroacoustic transducer of the access control system. The confirmation signal may include information on a time at which the portable user device transmitted the acoustic signal.

[0035] The radio interface may be a Bluetooth Low Energy, BLE, interface. The BLE interface allows electronic keys to be implemented at moderate additional cost, because cellular phones and many other portable user devices that can act as electronic keys are provided with BLE interfaces. Active transponders may be equipped with a BLE interface at moderate additional costs.

[0036] The radio interface may be or may include a legacy Bluetooth interface, a Long Term Evolution (LTE) machine-to-machine (M2M) interface, a Zigbee interface, or other radio communication interfaces.

[0037] The portable user device may further comprise an optical sensor. The optical sensor may comprise a photodiode or a camera chip, as provided in cellular phone, for example. The control circuit may be coupled to the optical sensor. Based on an output signal of the optical sensor, the control circuit may determine whether the microphone or loudspeaker of the portable user device is likely to be occluded, e.g., because the portable user device is located in a pocket, bag, or other enclosure that may block the acoustic signal. Operational conditions that may prevent successful transmission of the acoustic signal may be reliably determined.

[0038] The control circuit may be configured to selectively request, based on an output signal of the optical sensor, a user input action to confirm that access is intended. This allows the user's intent to be verified by a dedicated user input action if the portable user device is located in a pocket, bag, or other enclosure which attenuates the acoustic signal transmission.

[0039] The portable user device may further comprise a user interface configured to output operational information associated with the access control system if the portable user device is positioned proximate the access control system for at least a threshold time period. The portable user device may be configured to selectively allow the user to configure a locking system via the portable user device if the portable user device is positioned proximate the access control system for at least a threshold time period.

[0040] The portable user device may be a portable active transponder.

[0041] The portable user device may be a cellular phone.

[0042] A system according to an embodiment comprises an access control system according to an embodiment and a portable user device according to an embodiment. The access control system may be integrated in a locking cylinder or a door handle unit.

[0043] A method of controlling access comprises receiving a signal from a portable user device at a radio interface of an access control system. The method comprises triggering transmission of an acoustic signal between an electroacoustic transducer of the access control system and the portable user device in response to the signal from the portable user device. The method comprises selectively activating an actuator in an access grant procedure based on a propagation time of the acoustic signal between the electroacoustic transducer and the portable user device

[0044] As described for the access control systems and portable user devices according to embodiments, the method allows the user's intent to obtain access to a certain area to be verified even when multiple electronic door locks are located within the radio communication range of the portable user device. Alternative or additionally, fraudulent relaying attacks may be detected.

[0045] The access grant procedure may comprise a verification of the credential, e.g., by verifying that the portable user device is authorized to be granted access, before the actuator is activated. Additional verification steps may be implemented. For illustration, the amplitude of the acoustic signal may be evaluated to determine whether the portable user device is located inside or outside of the area to which access is desired. The actuator may be activated only if the portable user device is located outside of the area, but not when the portable user device is located inside of this area. Unintentional unlocking of a door, for example, may be prevented if the portable user device is already in the area protected by the access control system.

[0046] The method may be performed using an access control system according to an embodiment and/or a portable user device according to an embodiment.

[0047] The radio interface may be a Bluetooth Low Energy (BLE) interface. The method may comprise scanning, by the access control system, for a BLE advertising signal from the portable user device. The method may comprise generating, by the access control system, a BLE advertising signal.

[0048] Triggering the transmission of the acoustic signal may comprise activating a loudspeaker of the access control system to transmit the acoustic signal from the access control system to the portable user device. Triggering the transmission of the acoustic signal may comprise requesting, by the access control system, the portable user device to output the acoustic signal for transmission to a microphone of the access control system.

[0049] Irrespective of whether the acoustic signal is transmitted from the access control system to the portable user device or vice versa, the acoustic signal may be a sound signal. The sound signal may be modulated to facilitate the sound signal to be discriminated from ambient sounds. The sound signal may also carry information encoded therein. The information may be encoded in a frequency, amplitude, time duration, repetition rate, and/or duration between successive repetitions of the sound signal, for example. The information may also be encoded in changes of frequency, amplitude, or other characteristics of the sound signal.

[0050] The method may further comprise determining, by the access control system, whether the portable user device is within a pre-determined distance range from the electroacoustic transducer of the access control system and selectively granting access if the portable user device is within the pre-determined distance range and if the portable user device is authenticated to be entitled to access.

[0051] The method may further comprise allowing the user to view and/or modify configuration information for a locking system which includes the access control system, if the portable user device is held in proximity of the access control system for at least a pre-determined time period.

[0052] In the access control systems and methods according to embodiments, the actuator that is activated to grant access may be an electromechanical actuator. The electromechanical actuator may be operative to release a latch, a catch, or another member that maintains a lock in a closed position.

[0053] The method may further comprise determining, by the access control system, whether the portable user device is located outside or inside of the area protected by the access control system. The amplitude of the acoustic signal may be used as an indicator for whether the portable user device is located inside or outside of the area.

[0054] The actuator may be selectively activated if the following conditions are fulfilled cumulatively: the propagation time indicates that the portable user device is located within a pre-determined range from the access control system, the portable user device is authenticated to be entitled to access, and the portable user device is located outside of the area to which access is to be granted. If one or several of these conditions is not fulfilled, access may be denied.

[0055] Embodiments of the invention may in particular be used for electronic locks associated with doors in buildings, such as building entrance doors, office doors, or doors to residential rooms. Embodiments of the invention allow the user's intent to unlock an electronic lock to be detected based on a propagation time of an acoustic signal. The propagation time of the acoustic signal may be measured using existing hardware, such as a microphone of a cellular phone and a loudspeaker of an electronic locking cylinder, or dedicated hardware. The propagation time measurement allows radio communication techniques to be used which have a communication range that may cover multiple electronic locks, as may be the case for a BLE interface, for example, without requiring time-consuming user input actions to verify which door the user intends to unlock.

BRIEF DESCRIPTION OF THE DRAWINGS

[0056] Embodiments of the invention will be described in detail with reference to the drawings in which like or identical reference signs are used to designate like or identical elements.

Fig. 1 is a schematic view of a system according to an embodiment.

Fig. 2 is a block diagram representation of an access control system and a portable user device according to an embodiment.

Fig. 3 is a block diagram representation of an access control system and a portable user device according to an embodiment.

Fig. 4 is a block diagram representation of an access control system and a portable user device according to an embodiment.

Fig. 5 is a schematic view of a system according to an embodiment.

Fig. 6 is a signalling diagram for illustrating the operation of an access control system and a portable user device according to an embodiment.

Fig. 7 is a signalling diagram for illustrating the operation of an access control system and a portable user device according to an embodiment.

Fig. 8 is a signalling diagram for illustrating the operation of an access control system and a portable user device according to an embodiment.

Fig. 9 is a signalling diagram for illustrating the operation of an access control system and portable user device according to an embodiment.

Fig. 10 is a flow chart of a method according to an embodiment.

Fig. 11 is a flow chart of a method according to an embodiment.

DETAILED DESCRIPTION OF EMBODIMENTS

[0057] Embodiments of the invention will be described in detail with reference to the drawings. While embodiments will be described in the context of door locks and portable user devices that may be active transponders or cellular phones, it will be appreciated that the invention may be used in a wide variety of different fields, using various types of portable user devices that act as electronic keys.

[0058] Fig. 1 is a schematic view illustrating a system 1 according to an embodiment. An access control system may be arranged in a locking cylinder 3, a door handle 4, or a door fitting assembly of a door 2. The access control system may be operative to selectively unlock the door 2 by activation of an actuator. The actuator may be an electromechanical actuator that selectively displaces a latch, catch, or other member to unlock the door 2. A portable user device 20 may act as an electronic key configured to communicate with the access control system. As will be explained in more detail below, the access control system and portable user device 20 are operative to combine radio communication 5 and the unidirectional or bidirectional transmission of an acoustic signal 6 to determine whether access is to be granted by unlocking the door 2. The propagation time of the acoustic signal

6 is used as indicator for the distance between the portable user device 20 and the access control system and, thus, for the user's intent.

[0059] The acoustic signal 6 may be an audible signal. The acoustic signal 6 may have a frequency or may include plural frequencies in the range of audible frequencies, e.g., in the range from 20 to 20,000 Hz. This facilitates generation and detection of the acoustic signal 6 using hardware components that may already be present in the electronic lock and/or the portable user device 20.

[0060] The electronic access system and the portable user device 20 may be configured for radio communication in accordance with, e.g., Bluetooth Low Energy (BLE). BLE signals generated in accordance with or compatible with Bluetooth Core Specification Version 4.0, 4.1, or 4.2 may be transmitted and/or received by the electronic access system and the portable user device 20. Other radio communication techniques may be used in addition or as an alternative to BLE, such as legacy Bluetooth, Zigbee or Long Term Evolution (LTE) machine-to-machine (M2M) communication techniques.

[0061] Once the access control system has detected that an object is located in proximity to the access control system, the access control system and portable user device may start establishing communication over a radio interface. For illustration, the access control system may scan for BLE advertising signals from the portable user device or vice versa. Connection setup may be performed. Authentication information may be exchanged over the radio interface. Various implementations of such signalling that allows the access control system to determine whether the user of the portable user device is authorized to gain access are known to the skilled person and will not be described further herein. In addition to radio communication, the acoustic signal 6 is transmitted from the electronic access system to the portable user device 20 or vice versa, to allow the distance between electroacoustic transducers of the portable user device 20 and of the electronic access system to be estimated. The propagation time of the acoustic signal 6 is indicative of this distance.

[0062] Features of the access control system and the portable user device that may be implemented in various embodiments will be described with reference to Fig. 2 to Fig. 11 below.

[0063] Fig. 2 is a block diagram representation of a system 1 comprising an access control system 10 and a portable user device 20 according to an embodiment. The access control system 10 may be disposed, or configured to be disposed, within a cavity defined within a housing of a locking cylinder or within a shell of a door handle.

[0064] The access control system 10 generally comprises a control circuit 11, a radio interface 12, and an electroacoustic transducer which may comprise a loudspeaker 14. The control circuit 11 may comprise at least one integrated circuit. The control circuit 11 may comprise an application specific integrated circuit, a controller, a microcontroller, a processor, a microprocessor, or a combination of multiple such integrated circuits. The radio interface 12 may be a BLE interface. The loudspeaker 14 may be configured to generate an acoustic signal.

[0065] The access control system 1 may be coupled to an electromechanical actuator 7 or may comprise the electromechanical actuator 7. The control circuit 11 may be configured to selectively activate the actuator 7 to grant access, e.g., by unlocking a door.

[0066] The portable user device 20 generally comprises a control circuit 21, a radio interface 22, and an electroacoustic transducer which may comprise a microphone 23. The control circuit 21 may comprise at least one integrated circuit. The control circuit 21 may comprise an application specific integrated circuit, a controller, a microcontroller, a processor, a microprocessor, or a combination of multiple such integrated circuits. The radio interface 22 may be a BLE interface. The microphone 23 may be configured to detect the acoustic signal generated by the loudspeaker 14 of the access control system. The portable user device 20 may be an active transponder or a cellular phone, for example.

[0067] In operation, one of the access control system 10 and the portable user device 20 may operate in BLE advertising mode, and the other one of the access control system 10 and the portable user device 20 may operate in scan mode to detect BLE advertising. A radio connection may optionally be set up between the radio interface 12 of the access control system 10 and the radio interface 22 of the portable user device 20. In order to determine whether the portable user device 20 is located in proximity to the access control system 10, the control circuit 11 may cause the loudspeaker 14 to output the acoustic signal. The acoustic signal may be modulated or otherwise encoded to facilitate detection even in the presence of ambient sound. The control circuit 11 may cause the loudspeaker 14 to output the acoustic signal in response to a radio signal received at the radio interface 12 from the portable user device 20. The radio signal that causes the control circuit 11 to initiate transmission of the acoustic signal may be a BLE advertising signal, a BLE scan response, a signal received from the portable user device 20 for BLE connection setup, or a signal received from the portable user device 20 after BLE connection setup.

[0068] The control circuit 21 of the portable user device 20 may monitor an output signal of the microphone 23 to detect receipt of the acoustic signal generated by the loudspeaker 14. In response to detecting the acoustic signal, the control circuit 21 may cause the radio interface 22 to transmit a confirmation message to the access control system 10. The confirmation message may include time information. The time information may indicate the time at which the microphone 23 detected receipt of the acoustic signal generated by the loudspeaker 14. This time may be provided with reference to, for example, a reference time defined by one of the signals transmitted in the BLE advertising or BLE connection setup. The time

information may also indicate the propagation time of the acoustic signal. To this end, information on the transmit time at which the loudspeaker 14 transmits the acoustic signal may be provided to the portable user device 20 via the radio interface 22. The control circuit 21 of the portable user device 20 may determine the propagation time and report it back to the access control system 10.

[0069] The access control system 10 may determine, based on the propagation time of the acoustic signal, whether the distance between the loudspeaker 14 and the microphone 23 is less than a pre-determined threshold. To this end, the propagation time of the acoustic signal may be compared to a time threshold. The time threshold may be from 0.1 to 2.0 ms. The time threshold may be from 0.2 to 1.0 ms. The time threshold may be from 0.2 to 0.5 ms. The time threshold may be approximate 0.3 ms. This allows the access control system 10 to determine whether the portable user device 20 is located within a pre-determined range of approximately 30 cm, for example, from the access control system 10. The control circuit 11 may activate the actuator 7 to grant access if the measured propagation time for the acoustic signal meets a threshold criterion that indicates that the portable user device 20 is located within a pre-determined range from the access control system 10, and if authorization information received from the portable user device 20 at the radio interface 12 indicates that the portable user device 20 is authorized to be granted access.

[0070] The access control system 10 may determine, based on an amplitude of the acoustic signal, whether the portable user device 20 is located outside of the area protected by the access control system. The control circuit 11 may activate the actuator 7 to grant access if the measured propagation time for the acoustic signal meets a threshold criterion that indicates that the portable user device 20 is located within a pre-determined range from the access control system 10, if authorization information received from the portable user device 20 at the radio interface 12 indicates that the portable user device 20 is authorized to be granted access, and if the amplitude of the acoustic signal indicates that the portable user device 20 is located outside of the area protecte4d by the access control system 10. Otherwise, access is denied.

[0071] Fig. 3 is a block diagram representation of a system 1 comprising an access control system 10 and a portable user device 20 according to an embodiment. The system 1 illustrated in Fig. 3 may be operative to transmit the acoustic signal from the portable user device 20 to the access control system 10.

[0072] The access control system 10 comprises a control circuit 11 and a radio interface 12 which may be configured as described with reference to Fig. 2. The access control system 10 comprises an electroacoustic transducer implemented as a microphone 13 to detect an acoustic signal generated by the portable user device 20 for performing a propagation time measurement.

[0073] The portable user device 20 comprises a control circuit 21 and a radio interface 22 which may be configured as described with reference to Fig. 2. The portable user device 20 comprises an electroacoustic transducer implemented as a loudspeaker 24 to generate the acoustic signal for performing a propagation time measurement.

[0074] In operation, BLE advertising and, optionally, BLE connection setup may be performed. The control circuit 11 may control the radio interface 12 to transmit a BLE advertising signal, a BLE scan response, or another signal during or after BLE connection setup, to cause the control circuit 21 of the portable user device 21 to control the loudspeaker 24 to generate the acoustic signal. The control circuit 11 may monitor an output signal of the microphone 13 to determine the propagation time of the acoustic signal from the loudspeaker 24 to the microphone 13. To allow the control circuit 11 to determine the propagation time, the portable user device 21 may transmit information on the time at which the acoustic signal was generated to the access control system 10 via the radio interface 22. The time may be specified in relation to a radio signal, such as a BLE advertising signal, a BLE scan response, or another signal. Alternatively, the portable user device 21 may output the acoustic signal via the loudspeaker 24 at a time that is fixed relative to a radio signal, such that no dedicated signal needs to be transmitted to the access control system 10 to inform the access control signal 10 of the transmit time.

[0075] The access control system 10 may determine, based on the propagation time of the acoustic signal, whether the distance between the loudspeaker 14 and the microphone 23 is less than a pre-determined threshold. To this end, a threshold comparison may be performed for the propagation time, as was described with reference to Fig. 2.

[0076] In any one of the embodiments, the access control system 10 and/or the portable user device 20 may comprise additional components. Exemplary additional components will be explained with reference to Fig. 4.

[0077] Fig. 4 is a block diagram representation of a system 1 comprising an access control system 10 and a portable user device 20 according to an embodiment. The access control system 10 comprises an electroacoustic transducer which may include a microphone 13 and/or a loudspeaker 14. The portable user device 20 comprises an electroacoustic transducer which may comprise a microphone 23 and/or a loudspeaker 24. The access control system 10 and the portable user device 20 are configured such that an acoustic signal may be transmitted at least in a unidirectional manner, as explained with reference to Fig. 1 to Fig. 3 above.

[0078] The access control system 10 may comprise a presence detector 15. The presence detector 15 may be operative to determine presence of an object, such as a metal object or another object, in proximity to the access control system 10. The presence detector 15 may comprise a resonant circuit having a resonance frequency that is shifted by the presence of the portable user device 20, for example. The frequency shift may be detected by

the access control system 10 to sense presence of the portable user device 20. Other presence detectors may be used, such as an optical presence detector. The access control system 10 may be configured such that the radio interface 12 wakes up to a BLE scan mode or to a BLE advertising mode only when the presence detector 15 detects presence of an object that could be the portable user device 20. Thereby, lifetime of a battery 16 which supplies the access control system 10 with energy may be prolonged. The battery 16 may be installed, together with the other components of the access control system 10, in an inner cavity of a locking cylinder or door handle to facilitate installation of the access control system 10, without requiring external power supply connections.

[0079] The portable user device 20 may comprise a wake-up circuit that allows the portable user device 20 to be woken up by the access control system 10 by means of a wake-up signal. The wake-up signal may be an electromagnetic signal, such as an electromagnetic pulse.

[0080] The portable user device 20 may comprise an optical sensor 25. The optical sensor 25 may comprise a photodiode. The optical sensor 25 may comprise a camera chip. It will be appreciated that many cellular phones are equipped with a camera chip at any rate, and that the camera chip of the cellular phone may be used as optical sensor 25 if the cellular phone acts as electronic key. When the portable user device 20 fails to detect an acoustic signal from the access control system 10, the control circuit 21 may process an output of the optical sensor 25 to determine whether the portable user device 20 is in an operational condition in which the microphone 23 of the portable user device 20 is partially occluded. This may be the case when the portable user device 20 is located in a pocket, bag, or other enclosure while the access control system 10 attempts to perform an acoustic signal propagation time measurement. In response to detecting that the microphone 23 of the portable user device 20 is partially occluded, the portable user device may request a dedicated user input action to confirm the user's intent to unlock a door.

[0081] The portable user device 20 may comprise a graphical user interface 26. The graphical user interface 26 may be operative to output information on a configuration of the locking system of which the access control system 10 is a part. For illustration, a home or office locking system may comprise a plurality of access control systems, at least some of which may be configured in the same manner as described for the access control system 10. The portable user device 20 may output via the graphical user interface 26 information on the electronic locks and, optionally, the electronic keys that are registered for the locking system. This may be done selectively if the portable user device 20 has a master functionality that allows this information to be displayed and/or reconfigured. The graphical user interface 26 may be operative to allow the user to reconfigure the locking system of which the access control system 10 is a part. For illustration, the graphical user interface 26 may allow the user to re-assign authorization for electronic key(s) to unlock various electronic locks, using the portable user device 20. The portable user device 20 may allow the user to perform at least one of the following actions: reading out locking states (locked/unlocked) of one or several electronic locks; reading out charging states of batteries of one or several electronic locks; reading out states of one or several doors (closed/open); reading out other operational data of one or several electronic locks; reading out inspection protocols for one or several electronic locks; performing programming tasks; and/or reading out an electronic lock, e.g., by reading out which electronic keys have been used to unlock the electronic lock in the past.

[0082] The displaying of configuration information and/or the initiation of an operation mode that allows the user to reconfigure the locking system via the portable user device 20 may be triggered selectively, e.g., when the portable user device 20 is positioned next to the access control system 10 for at least a threshold time period.

[0083] The portable user device 20 may be configured to communicate over a wide area network (WAN), a local area network (LAN), a wireless local area network (WLAN), Wi-Fi, or other techniques with at least one computer connected to the wide area network to display information on and/or reconfigure the locking system. The portable user device 20 may comprise a cellular interface, which may be a GSM, USTM, 3G, LTE, or LTE-A communication interface, which allows the portable user device 20 to communicate with the computer over a packetized connection to display information on and/or reconfigure the locking system.

[0084] Various effects are attained by the access control system and portable user device according to embodiments. For illustration, the user's intent to be granted access by the access control system 10 may be reliably detected based on the propagation time of the acoustic signal. No lengthy, time-consuming user interaction is required for this purpose. Moreover, the decision to grant access may be made based on the authorizations given to the portable user device 20 and the propagation time of the acoustic signal, but independently of the orientation in which the portable user device 20 is held. This reduces the burden of the acts the user needs to perform to unlock a door, for example. Moreover, the risk of fraudulent relaying attacks may be mitigated, as will be explained in more detail with reference to Fig. 6.

[0085] Fig. 5 is a schematic view of a system 1 according to an embodiment. A relaying attack is a fraudulent procedure that can be detected using the techniques described herein. A portable user device 20 is authorized to unlock plural regions, e.g., by unlocking the electronic locks of different doors 2, 8. In a relaying attack, a different portable user device 31 relays radio signals 5 transmitted from the portable user device 20 to the access control system of the door 8 while the portable user device 20

is being used to unlock a different door 2 remote from the door 8. This may be done directly or via one or more intermediate device(s) 32. The relayed radio signal(s) 5', 5" may include information that, in the absence of further safety measures, might be suitable to unlock the door 8. However, using the techniques disclosed herein, the access control system installed in the door 8 will determine the propagation time of an acoustic signal 6' between the access control system of the door 8 and the portable user device 20 from which the radio signal(s) 5 originate. The propagation time allows the access control system of the door 8 to detect that the portable user device 20 is located outside of a pre-determined distance range, which is indicative of a fraudulent relaying attack. While relaying attacks have been described in the context of doors granting access to different areas, the detection of fraudulent relaying attacks may also be suitable in other applications.

[0086] Operation and signalling between the access control system 10 and the portable user device 20 will be described in more detail with reference to Fig. 6 to Fig. 11 below. For better understanding, the various signalling diagrams indicate transmissions of both radio and acoustic signals, the latter being indicated by broken lines.

[0087] Fig. 6 is a signalling diagram for illustrating operation of the access control system 10 and the portable user device 20. The access control system 10 may perform a presence detection 41. Presence of an object that could be the portable user device 20 may be detected based on a resonance frequency of a resonant circuit, using optical techniques, or in other ways. One or several radio signal(s) 42 may be transmitted between the access control system 10 and the portable user device 20. The radio signal(s) 42 may include a BLE advertising signal and a BLE scan response. The radio signal(s) 42 may optionally include BLE connection setup signalling. An acoustic signal 43 may be transmitted from the access control system 10 to the portable user device 20 and/or vice versa. A confirmation signal 44 or several confirmation signals may carry information that allows the access control system 10 to determine the propagation time of the acoustic signal 43. It will be appreciated that, due to the radio signalling, a common reference time may be established by the access control system 10 and the portable user device 20, which may be used for determining the propagation time of the acoustic signal 43. Data indicating the authorization of the portable user device 20 for the unlocking operation may be included as payload in the radio signal(s) 42 or the confirmation signal(s) 44. An unlocking operation 57 may be performed by activating an electromechanical actuator. The unlocking operation 57 may be performed selectively if the propagation time indicates that the portable user device 20 is within a pre-determined distance range from the access control system 10 and if authentication information indicates that the portable user device 20 is authorized to be granted access.

[0088] Fig. 7 is a signalling diagram for illustrating operation of the access control system 10 and the portable user device 20. In the signalling illustrated in Fig. 7, the access control system 10 may be operative in a BLE scan mode and the portable user device 20 may be operative in a BLE advertising mode. In the signalling illustrated in Fig. 7, the access control system 10 may be operative to transmit an acoustic signal 55, and the portable user device 20 may be operative to detect the acoustic signal 55 and report the detection to the access control system 10.

[0089] The access control system 10 may perform a presence detection 51. Presence of an object that could be the portable user device 20 may be detected based on a resonance frequency of a resonant circuit, using optical techniques, or in other ways. In response to detecting presence of an object that could be the portable user device 20, the access control system 10 starts BLE scanning in a BLE scan mode 52. The radio interface of the access control system 10 may remain inactive until presence of an object has been detected. It is the presence detection that may wake up the BLE interface from an inactive or sleep state. Optionally, the radio interface of the access control system 10 may intermittently wake up for BLE scan mode operation, to ensure that the portable user device 20 could be detected via the radio interface even if the presence detector does not work properly. The portable user device 20 may transmit a BLE advertising signal 53 or several BLE advertising signals which are detected by the access control system 10.

[0090] One or several radio signal(s) 54 may be transmitted between the access control system 10 and the portable user device 20. The radio signal(s) 54 may include a BLE scan response. The radio signal(s) 54 may optionally include BLE connection setup signalling. An acoustic signal 55 may be transmitted from the access control system 10 to the portable user device 20 and/or vice versa. A confirmation signal 56 or several confirmation signals may carry information that allows the access control system 10 to determine the propagation time of the acoustic signal 55. The radio signalling allows a common reference time to be established by the access control system 10 and the portable user device 20, which may be used for determining the propagation time of the acoustic signal 55. Data indicating the authorization of the portable user device 20 for the unlocking operation may be included as payload in the radio signal(s) 54 or the confirmation signal(s) 56. An unlocking operation 57 may be performed selectively, as described above.

[0091] Fig. 8 is a signalling diagram for illustrating operation of the access control system 10 and the portable user device 20. In the signalling illustrated in Fig. 8, the access control system 10 may operate in a BLE scan mode and the portable user device 20 may operate in a BLE advertising mode. In the signalling illustrated in Fig. 8, the portable user device 20 may be operative to transmit an acoustic signal 58, and the access control system 10 may be operative to detect the acoustic signal 58. The

presence detection 51, BLE scan mode operation 52, BLE advertising 53, and radio signal(s) 54 may be implemented as described with reference to Fig. 7. The acoustic signal 58 may be generated by the portable user device 20. The acoustic signal 58 may be generated at a fixed time, e.g., relative to a BLE scan response, or information on the transmit time may be included in a confirmation signal 59. Data indicating the authorization of the portable user device 20 for the unlocking operation may be included as payload in the radio signal(s) 54 or the confirmation signal(s) 59. An unlocking operation 57 may be performed selectively, as described above.

[0092] Fig. 9 is a signalling diagram for illustrating operation of the access control system 10 and the portable user device 20. In the signalling illustrated in Fig. 7, the access control system 10 may be operative in a BLE advertising mode and the portable user device 20 may be operative in a BLE scan mode 62. The access control system 10 may start BLE advertising 63 when the presence detection 51 detects an object that could be the portable user device 20. The radio interface of the access control system 10 may remain inactive until presence of an object has been detected. It is the presence detection that may wake up the BLE interface from an inactive or sleep state. Optionally, the radio interface of the access control system 10 may intermittently wake up for BLE advertising mode operation, to ensure that the portable user device 20 could be detected via the radio interface even if the presence detector does not work properly. The access control system 10 may transmit a BLE advertising signal 63 or several BLE advertising signals which are detected by the portable user device 20. The subsequent transmission of additional radio signal(s) and of the acoustic signal may be implemented in any one of the various ways described with reference to Fig. 6 to Fig. 8 above.

[0093] In any one of the embodiments, the acoustic signal may have a frequency and/or duration and/or amplitude that may vary as a function of time. The acoustic signal may be modulated, by varying the frequency, duration, amplitude and/or time gaps between successive pulses of the acoustic signal, to facilitate discrimination of the sound signal from ambient sound. Alternatively or additionally, these techniques may also be used to encode information in the acoustic signal.

[0094] The acoustic signal may comprise coded information. The coded information may be unique for the access control system at least in the locking system to which the access control system belongs. Alternatively or additionally, the coded information may depend on the portable user device 20 which requests access. Safety may be further increased thereby. The information may be encoded in one or more of: a frequency of the acoustic signal, a duration of the acoustic signal, an amplitude of the acoustic signal, a repetition rate of the acoustic signal, and/or a time delay between repetitions of the acoustic signal, or combinations thereof.

[0095] The acoustic signal that is transmitted to verify that the portable user device 20 is located proximate to the access control system may also be used as an audible confirmation of the unlocking. I.e., when access is granted, no acoustic signal in addition to the acoustic signal that is used for the propagation time measurement is output by the access control system 10. If access is denied, a different audible failure signal may be output to indicate the failure of the access attempt.

[0096] The propagation time of the acoustic signal may be evaluated to verify that the portable user device 20 is located within a pre-determined range of less than 1 m, less than 50 cm, less than 40 cm, or about 30 cm from the access control system 10.

[0097] Fig. 10 is a flow chart of a method 70. The method 70 may be performed by an access control system 10 according to an embodiment. At 71, the access control system 10 determines, based on a propagation time of an acoustic signal transmitted from the access control system 10 to the portable user device 20 or vice versa, whether the portable user device 20 is located within a pre-determined distance range from the access control system. At 72, access is denied if the portable user device 20 is located outside of the pre-determined distance range. At 73, if the portable user device 20 is located within the pre-determined distance range from the access control system, the access control system 10 determines whether the portable user device 20 is held next to the access control system 10 for a duration which is at least a threshold time. At 76, if the duration does not meet the threshold criterion, it is determined whether the portable user device 20 is located outside of the area protected by the access control system. An amplitude of the acoustic signal may be compared to an amplitude threshold for that purpose. At 77, credential verification is performed. In this process, it is determined whether the portable user device 20 is authorized to obtain access. At 78, access is granted by activating actuator. At 74, if the duration meets the threshold criterion, credential verification is performed. In this process, it is determined whether the portable user device 20 is authorized to execute a maintenance routine. At 75, a maintenance routine may be executed by the portable user device 20. The maintenance routine allows the portable user device 20 to perform at least one of the following actions: reading out locking states (locked/unlocked) of one or several electronic locks; reading out charging states of batteries of one or several electronic locks; reading out states of one or several doors (closed/open); reading out other operational data of one or several electronic locks; reading out inspection protocols for one or several electronic locks; performing programming tasks; and/or reading out an electronic lock, e.g., by reading out which electronic keys have been used to unlock the electronic lock in the past. Steps 75 and 78 are executed only if the portable user device 20 is authorized to perform these acts. A specific authorization is necessary to perform step 75. The specific, master-type authorization of the portable user device 20 may be registered in the access control

system and/or a computer remote from the access control system.

[0098] Fig. 11 is a flow chart of a method 80. The method 80 may be performed by a portable user device 20 according to an embodiment. At 81, one or several radio signals are exchanged between the access control system 10 and the portable user device 20. At 82, the control circuit of the portable user device 20 determines whether an acoustic signal has been received from the access control system 10. At 83, if the acoustic signal has been received, a radio signal is generated to confirm receipt of the acoustic signal. The radio signal may also include information on a time of receipt or on the propagation time of the acoustic signal. At 84, if no acoustic signal has been detected, an output signal of an optical sensor may be read out by the control circuit of the portable user device 20. The optical sensor may comprise a photodiode or a camera chip, as may be provided in a cellular phone at any rate. Based on the output signal of the optical sensor, at 85 the control circuit determines whether the microphone of the portable user device 20 is likely to be occluded. If the output signal of the optical sensor indicates that the portable user device 20 is located within an enclosure, such as a pocket, bag, or other enclosure, the control circuit may determine that the microphone is likely to be also occluded. At 86, if the control circuit has determined that the microphone is likely to be occluded because the portable user device 20 is in an enclosure, a dedicated user confirmation may be requested. The dedicated user confirmation may be requested via a user interface of the portable user device 20, e.g., by requiring the user to actuate a touchscreen area, button or other confirmation element to confirm that access is intended. At 87, if it is determined that the microphone is not occluded, the access request may optionally be repeated.

[0099] While embodiments have been described in detail with reference to the drawings, modifications and alterations may be implemented in other embodiments. For illustration, while access control systems and portable user devices according to embodiments may have a BLE interface for radio communication, other radio interfaces may be used. The radio interfaces may be or may include a legacy Bluetooth interface, a Long Term Evolution (LTE) machine-to-machine (M2M) interface, a Zigbee interface, or other radio communication interfaces. In any one of the various embodiments, the interface(s) of the access control system 10 and of the portable user device 20 may be operative to transmit and receive signals in the 2.4 GHz band and/or other unlicensed bands.

[0100] While embodiments have been described in which the access control system may be arranged within an internal cavity of a locking cylinder or a smart door handle unit, the access control system may also be implemented in other forms. For illustration, the access control system may be incorporated in a control panel for installation adjacent to, but separately from a door. The access control systems may not only be used to selectively unlock doors, but may also be employed to grant access by selectively unlocking windows, grates, or other elements that may be provided with an electronic lock for safety reasons. While embodiments have been described in which the portable user device may be a cellular phone or an active transponder, the portable user device may also take other forms.

[0101] The devices, systems, and methods according to embodiments allow the user's intent to request access to be reliably determined while reducing the amount of required user interaction. The risk of fraudulent relaying attacks may be mitigated. The techniques may require only little additional power consumption in the access control system, which is beneficial in terms of battery lifetime.

Claims

1. An access control system (10), comprising:

   a radio interface (12) configured to communicate with a portable user device (20),
   an electroacoustic transducer (13, 14), and
   a control circuit (11) coupled to the radio interface (12) and to the electroacoustic transducer (13, 14), the control circuit (11) being configured to

   trigger transmission of an acoustic signal (6; 43; 55; 58) between the electroacoustic transducer (13, 14) and the portable user device (20) in response to a signal (42; 53; 54) received from the portable user device (20) at the radio interface (12); and
   selectively activate an actuator (7) in an access grant procedure based on a propagation time of the acoustic signal (6; 43; 55; 58) between the electroacoustic transducer (13, 14) and the portable user device (20).

2. The access control system (10) of claim 1, wherein the radio interface (12) is a Bluetooth Low Energy, BLE, interface.

3. The access control system (10) of claim 2, further comprising a presence detector (15) configured to detect presence of the portable user device (20), the control circuit (11) being coupled to the presence detector (15) and being configured to selectively activate the radio interface (12) based on an output signal of the presence detector (15).

4. The access control system (10) of claim 3, wherein the radio interface (12) is configured to start transmission of or scanning for a BLE advertising signal (53; 63) when the presence of the portable user device (20) is detected.

5. The access control system (10) of any one of the preceding claims,
wherein the control circuit (11) is configured to control the electroacoustic transducer (14) to generate the acoustic signal (6; 43; 55) in response to the signal (42; 53; 54) from the portable user device (20), and to process a confirmation signal (44; 56) received at the radio interface (12) from the portable user device (20) to determine the propagation time of the acoustic signal (6; 43; 55); or
wherein the control circuit (11) is configured to monitor an output signal of the electroacoustic transducer (13) to determine the propagation time of the acoustic signal (6; 43; 58).

6. The access control system (10) of any one of the preceding claims, wherein the control circuit (11) is configured to selectively activate the actuator (7) if all of the following conditions are fulfilled:

the propagation time indicates that the portable user device (20) is located within a pre-determined range from the access control system (10),
the portable user device (20) is authenticated to be entitled to access, and
an amplitude of the acoustic signal (6; 43; 55; 58) indicates that the portable user device (20) is located outside of the area to which access is requested.

7. The access control system (10) of any one of the preceding claims, wherein the acoustic signal (6; 43; 55; 58) is a sound signal, wherein the sound signal comprises coded information; optionally wherein the coded information is encoded in one or more of: a frequency of the acoustic signal (6; 43; 55; 58), an amplitude of the acoustic signal (6; 43; 55; 58), a duration of the acoustic signal (6; 43; 55; 58), a repetition rate of the acoustic signal (6; 43; 55; 58), and/or a time gap between successive pulses of the acoustic signal (6; 43; 55; 58).

8. A locking cylinder (3), door handle unit (4) or door fitting assembly, comprising the access control system (10) of any one of claims 1 to 7.

9. A portable user device (20), comprising:

a radio interface (22) configured to communicate with an access control system (10),
an electroacoustic transducer (23, 24), and
a control circuit (21) coupled to the radio interface (22) and to the electroacoustic transducer (23, 24), the control circuit (21) being configured to

control the radio interface (22) to transmit a signal (42; 53; 54) to the access control system (10),
monitor an output signal of the electroacoustic transducer (23) to detect receipt of an acoustic signal (6; 43; 55) from the access control system (10) or control the electroacoustic transducer (24) to generate an acoustic signal (6; 43; 58), and
control the radio interface (22) to transmit a confirmation signal (44; 56; 59) to the access control system (10) after receipt or transmission of the acoustic signal (6; 43; 55; 58).

10. The portable user device (20) of claim 9, wherein the electroacoustic transducer (23, 24) comprises a microphone (23) and, wherein the control circuit (21) is configured to monitor an output signal of the microphone to detect receipt of the acoustic signal (6; 43; 55) from the access control system (10) and to control the radio interface (22) to transmit the confirmation signal to the access control system (10) to confirm detection of the acoustic signal (6; 43; 55).

11. The portable user device (20) of claim 10, wherein the confirmation signal (44; 56) includes time information indicative of a time at which the portable user device (20) received the acoustic signal (6; 43; 55) or information on a propagation time of the acoustic signal (6; 43; 55) between the access control system (10) and the portable user device (20).

12. The portable user device (20) of any one of claims 9 to 11, wherein the radio interface (22) is a Bluetooth Low Energy, BLE, interface.

13. The portable user device (20) of any one of claims 9 to 12, further comprising

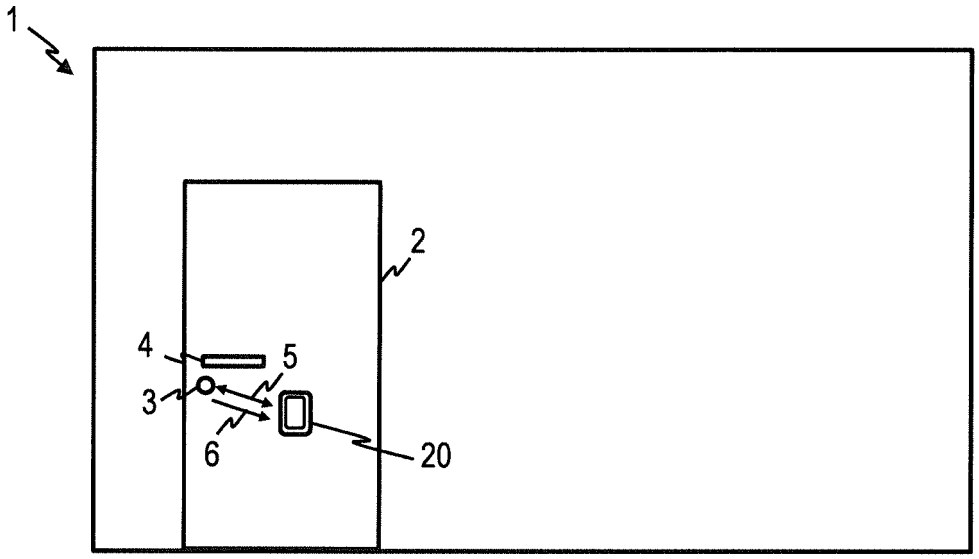
an optical sensor (25), wherein the control circuit (21) is coupled to the optical sensor (25) and is configured to selectively request, based on an output signal of the optical sensor (25), a user input action to confirm that access is intended; and/or
a user interface (26) configured to output operational information associated with the access control system (10) if the portable user device (20) is positioned proximate the access control system (10) for at least a threshold time period.

14. A system, comprising:

an access control system (10) of any of claims 1 to 7, optionally wherein the access control system (10) is integrated in a locking cylinder (3) or a door handle unit (4); and
a portable user device (20) of any of claims 9-13.

15. A method of controlling access, in particular for a door having a lock (3) or a door handle unit (4) comprising the access control system (10) of any of claims 1 to 7, the method comprising:

receiving a signal (42; 53; 54) from a portable user device (20) at a radio interface (12), in particular a Bluetooth Low Energy, BLE, interface of an access control system (10);
triggering transmission of an acoustic signal (6; 43; 55; 58) between an electroacoustic transducer (23, 24) of the access control system (10) and the portable user device (20) in response to the signal (42; 53; 54) from the portable user device (20); and
selectively activating an actuator (7) in an access grant procedure based on a propagation time of the acoustic signal (6; 43; 55; 58) between the electroacoustic transducer (23, 24) and the portable user device (20).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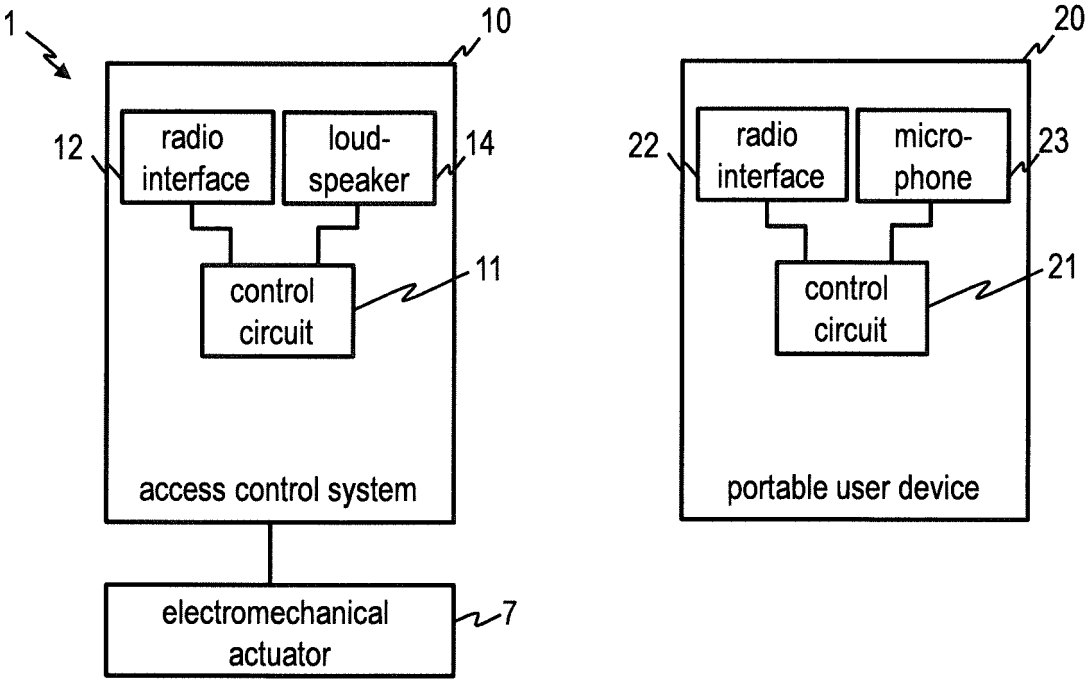
2
4
5
3
6
20

FIG. 1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radio interface
loud-speaker
14
control circuit
11
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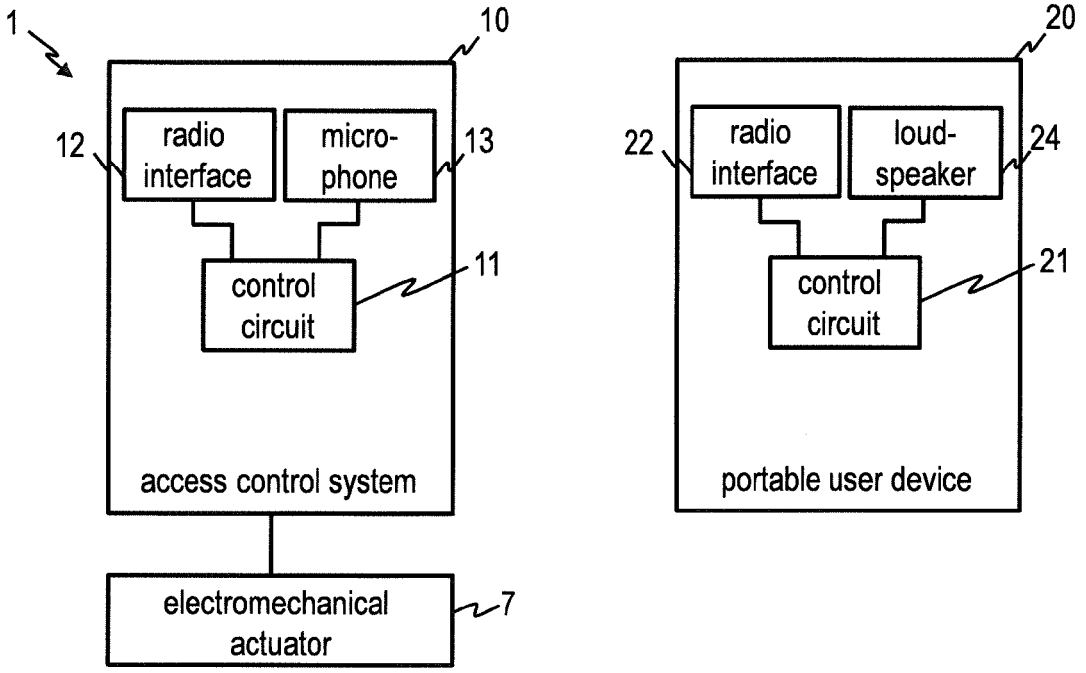
electromechanical actuator
7
20
22
radio interface
micro-phone
23
control circuit
21
portable user device

FIG. 2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10
12
radio interface
micro-phone
13
control circuit
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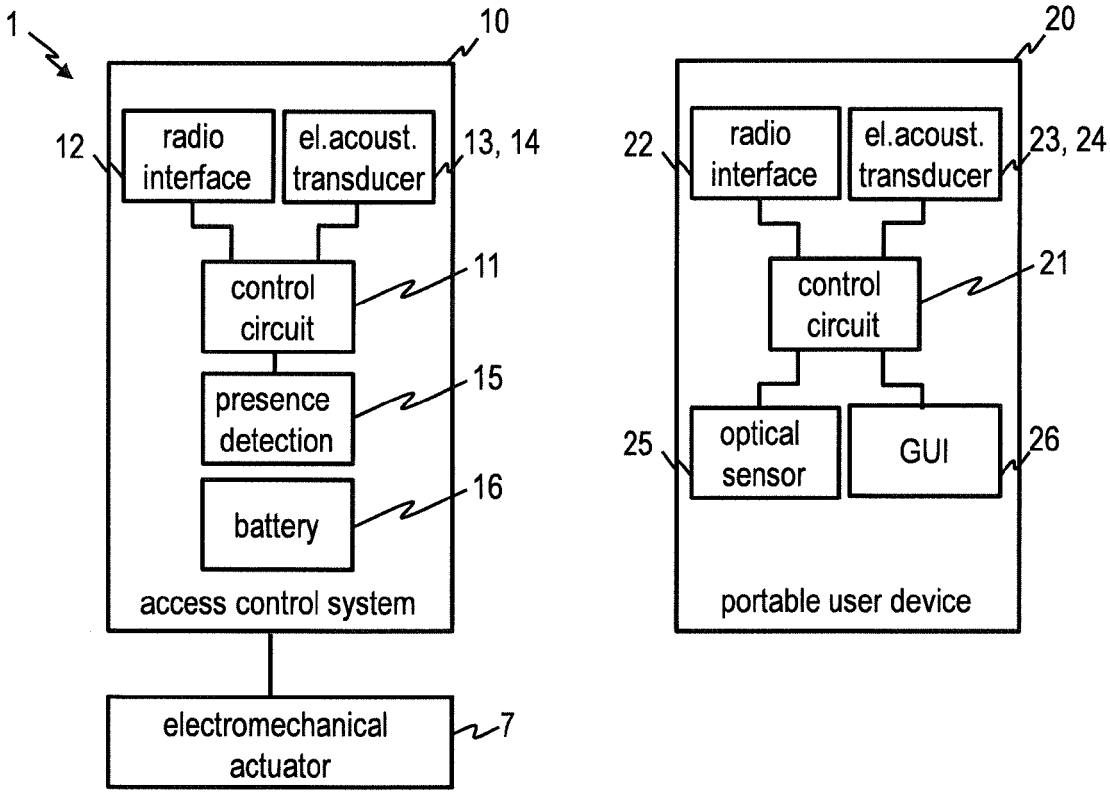
20
22
radio interface
loud-speaker
24
control circuit
21
portable user device

FIG. 3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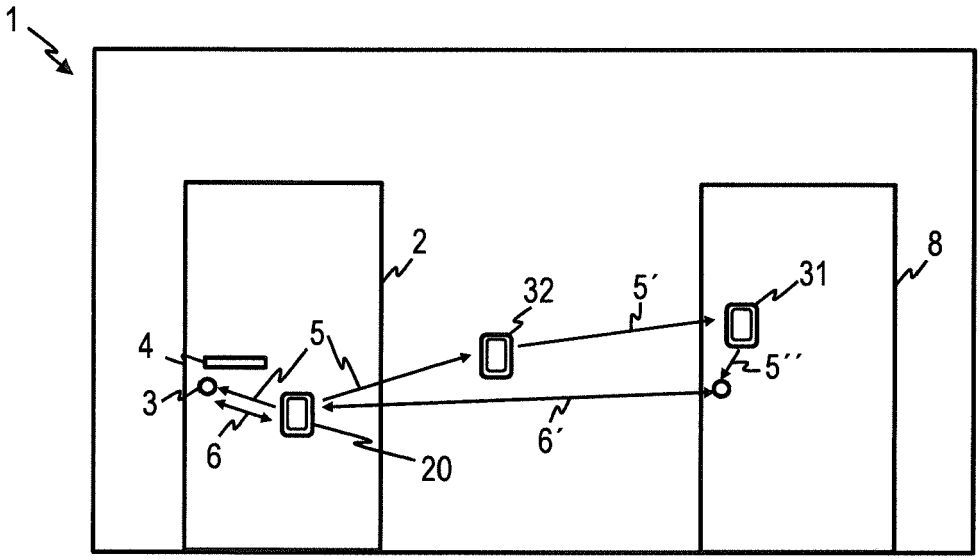
10
12
radio interface
el.acoust. transducer
13, 14
control circuit
11
presence detection
15
battery
16
access control system
electromechanical actuator
7
20
22
radio interface
el.acoust. transducer
23, 24
control circuit
21
optical sensor
25
GUI
26
portable user device

FIG. 4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2
8
32
5'
31
4
5
5''
3
6
6'
20

FIG. 5

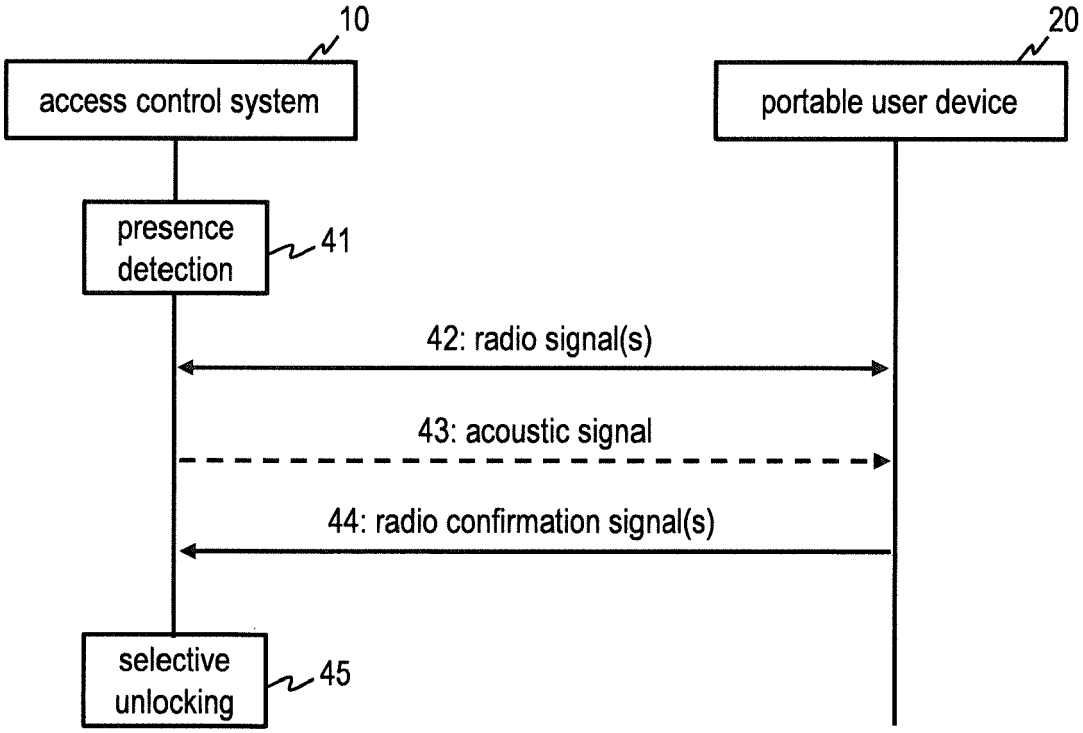
10
20
access control system
portable user device
presence detection
41
42: radio signal(s)
43: acoustic signal
44: radio confirmation signal(s)
selective unlocking
45

FIG. 6

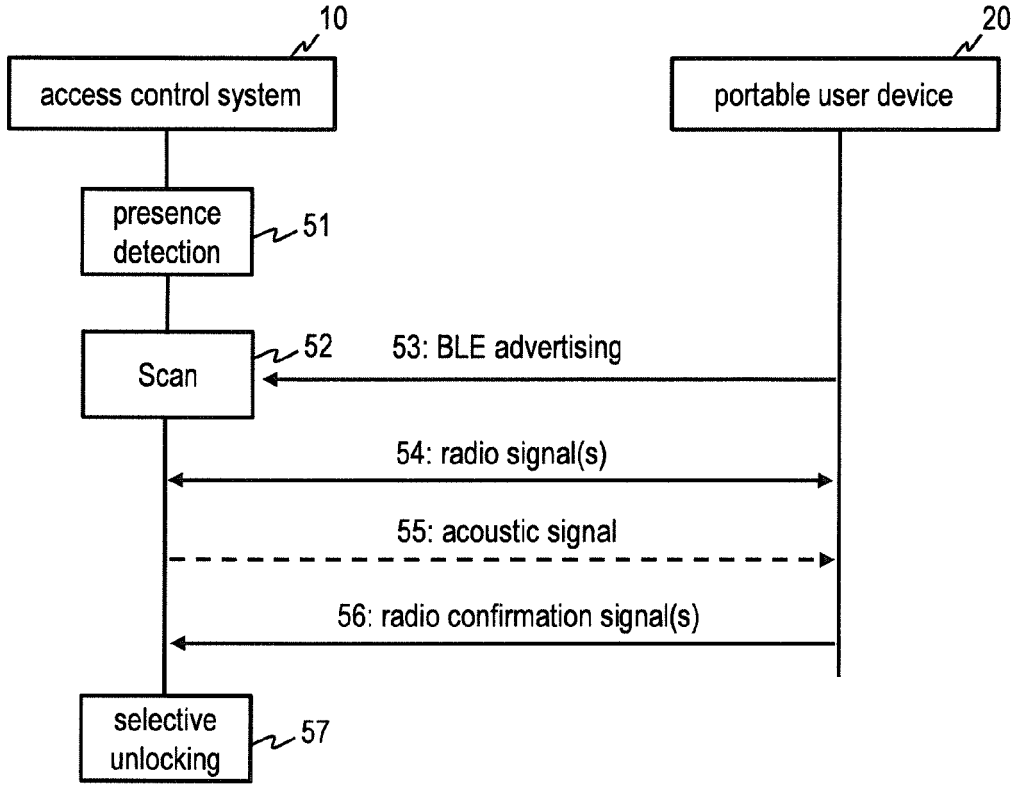
10
20
access control system
portable user device
presence detection
51
Scan
52
53: BLE advertising
54: radio signal(s)
55: acoustic signal
56: radio confirmation signal(s)
selective unlocking
57

FIG. 7

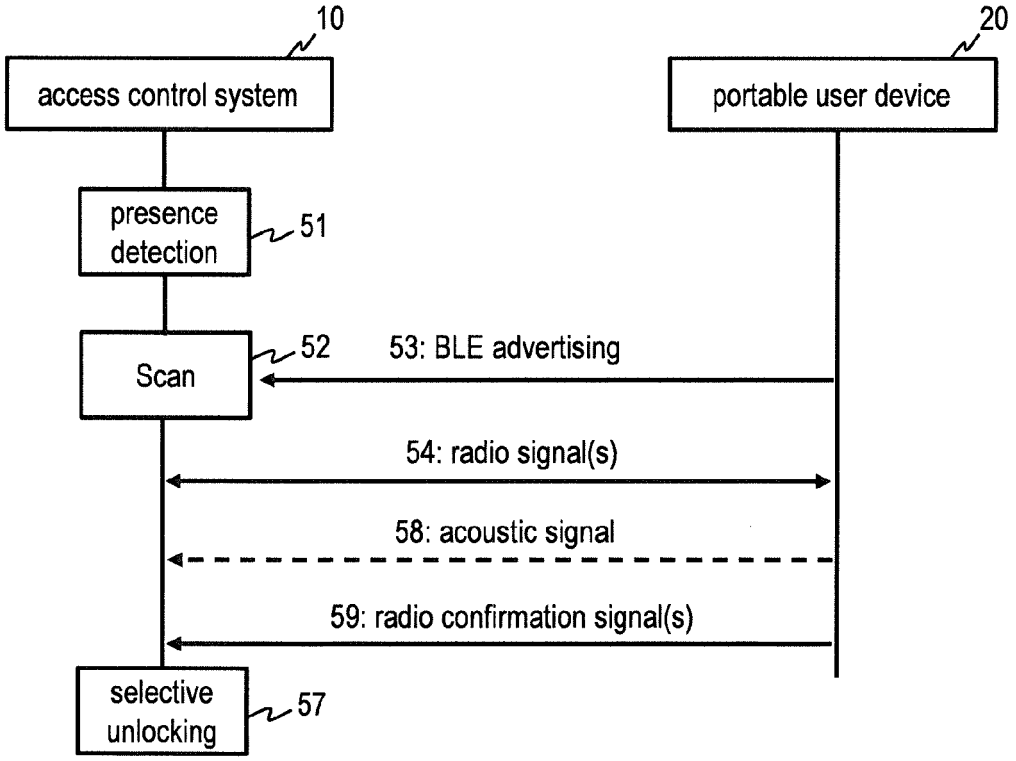
10
20
access control system
portable user device
presence detection
51
Scan
52
53: BLE advertising
54: radio signal(s)
58: acoustic signal
59: radio confirmation signal(s)
selective unlocking
57

FIG. 8

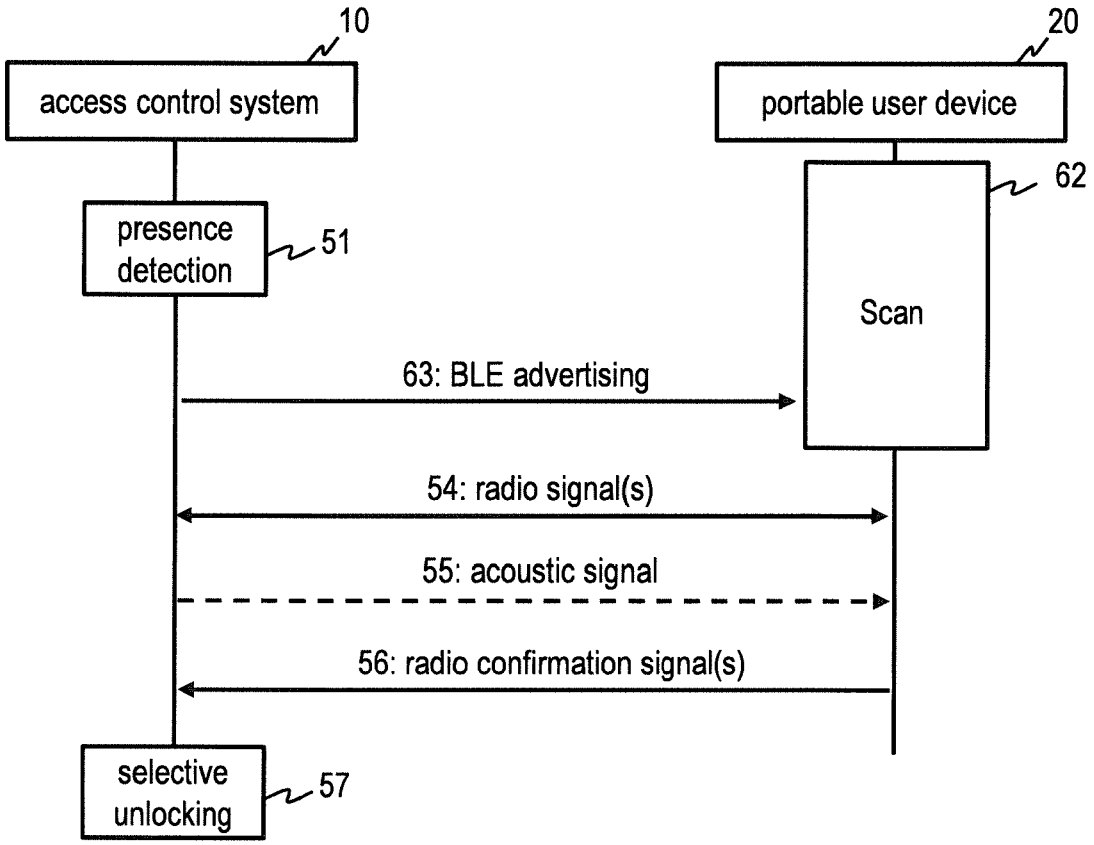
10
access control system
20
portable user device
62
presence detection
51
Scan
63: BLE advertising
54: radio signal(s)
55: acoustic signal
56: radio confirmation signal(s)
selective unlocking
57

FIG. 9

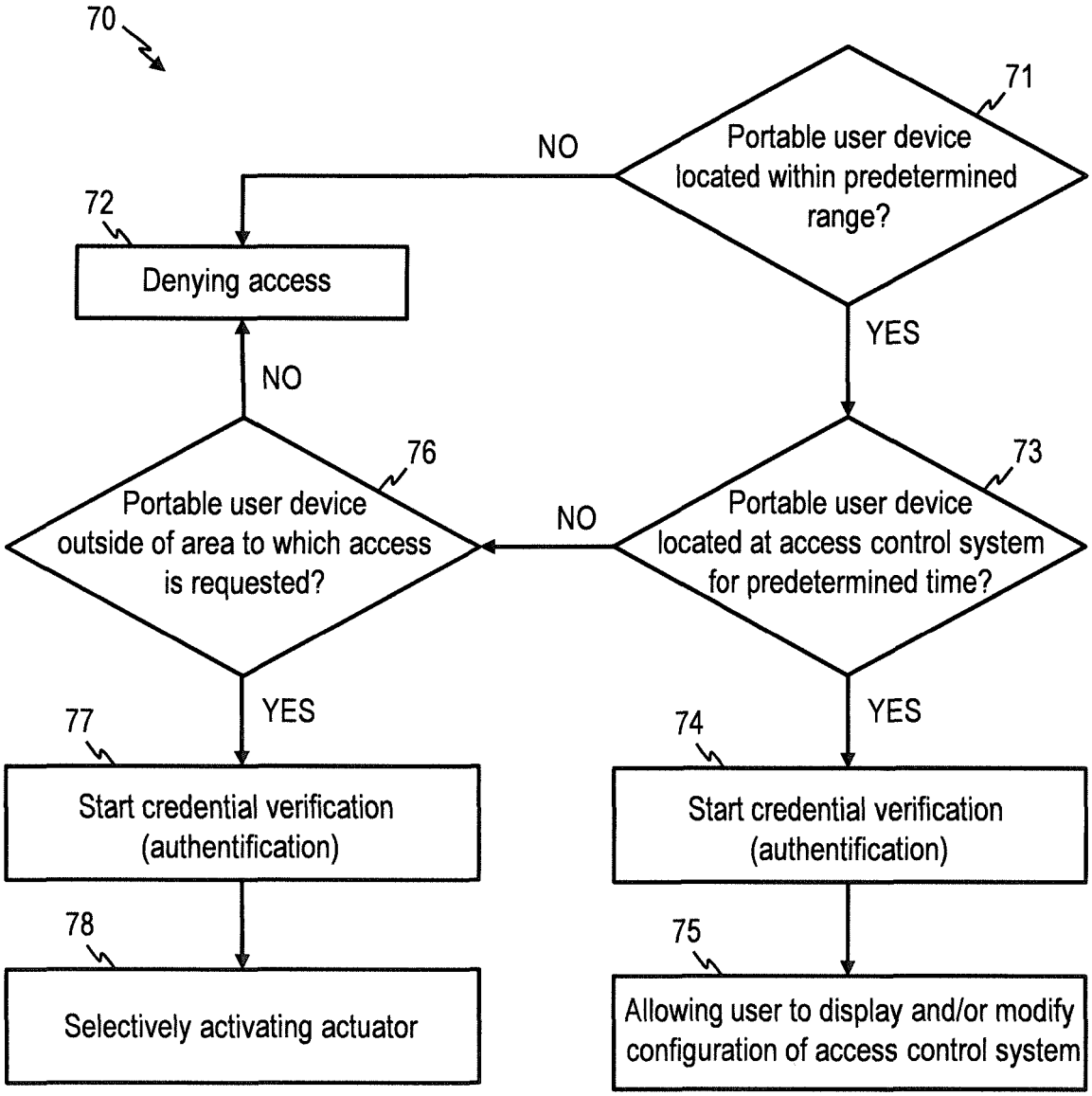
70
71
Portable user device located within predetermined range?
NO
YES
72
Denying access
NO
76
Portable user device outside of area to which access is requested?
NO
73
Portable user device located at access control system for predetermined time?
YES
YES
77
Start credential verification (authentification)
74
Start credential verification (authentification)
78
Selectively activating actuator
75
Allowing user to display and/or modify configuration of access control system

FIG. 10

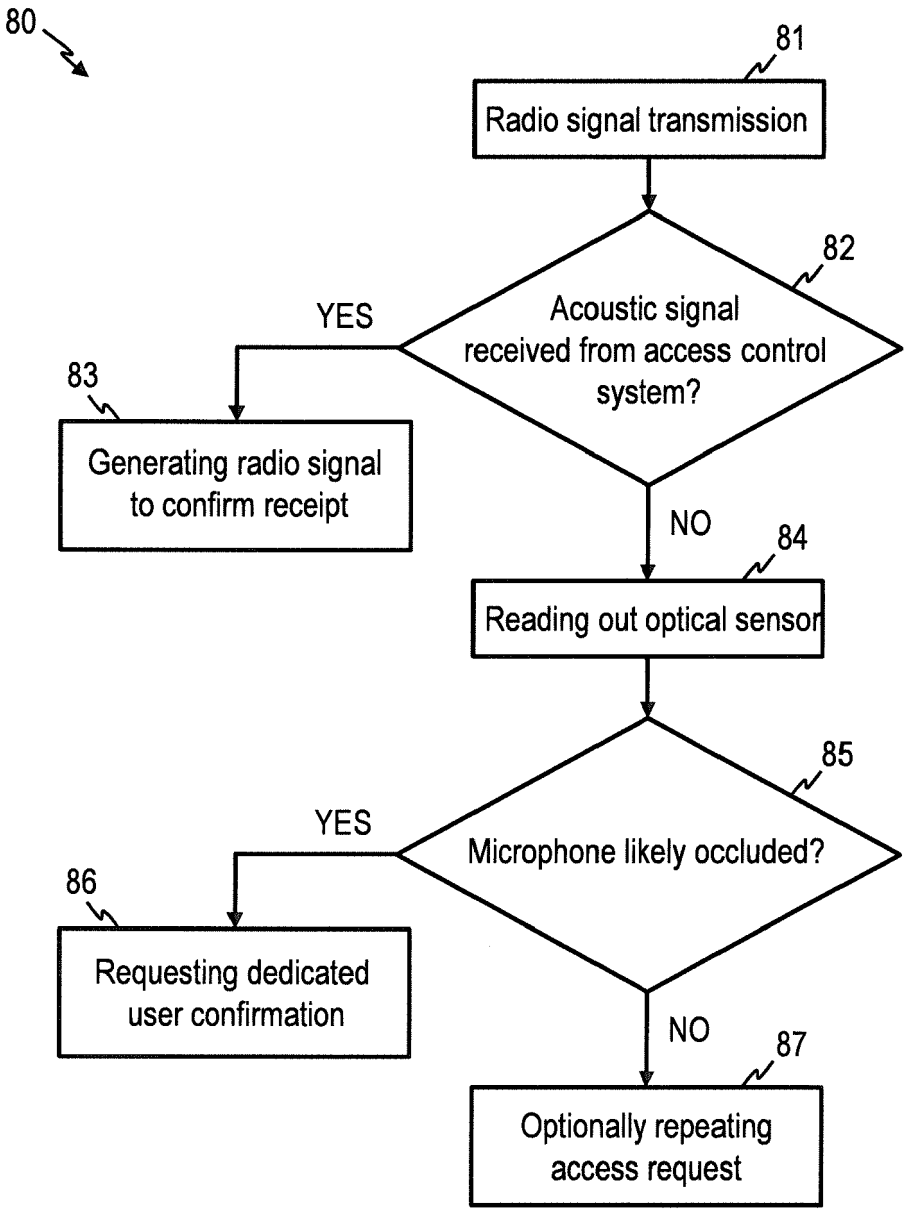
80
81
Radio signal transmission
82
Acoustic signal received from access control system?
YES
83
Generating radio signal to confirm receipt
NO
84
Reading out optical sensor
85
Microphone likely occluded?
YES
86
Requesting dedicated user confirmation
NO
87
Optionally repeating access request

FIG. 11

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EUROPEAN SEARCH REPORT

Application Number
EP 16 19 0310

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	US 2015/184628 A1 (FAN ZHIGANG [US]) 2 July 2015 (2015-07-02)	1,2,5, 7-12,14, 15	INV. G07C9/00
Y	* abstract * * paragraph [0004] * * paragraph [0042] - paragraph [0066] * * claims 1,4 * * figures 1-4 *	3,4,6,13	
Y	WO 2012/078158 A1 (UTC FIRE & SECURITY CORP [US]; ZACCHIO JOSEPH [US]; LAKAMRAJU VIJAYA R) 14 June 2012 (2012-06-14)	3,4	
A	* abstract * * paragraph [0001] - paragraph [0004] * * paragraph [0012] - paragraph [0034] * * figures 1-3 *	1,2,5, 7-12,14, 15	
Y	US 2014/077929 A1 (DUMAS PHILIP C [US] ET AL) 20 March 2014 (2014-03-20) * abstract * * paragraph [0007] - paragraph [0012] * * paragraph [0051] - paragraph [0057] * * paragraph [0069] - paragraph [0080] * * paragraph [0088] - paragraph [0089] * * paragraph [0141] *	6	TECHNICAL FIELDS SEARCHED (IPC) G07C
Y	EP 2 701 124 A1 (BEKEY AS [DK]) 26 February 2014 (2014-02-26) * abstract * * paragraph [0010] - paragraph [0019] * * paragraph [0024] - paragraph [0027] * * paragraph [0084] - paragraph [0086] * * paragraph [0098] - paragraph [0107] * * figures 1,4,5 *	13	

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~~The present search report has been drawn up for all claims~~

Place of search	Date of completion of the search	Examiner
The Hague	12 July 2017	Post, Katharina

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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& : member of the same patent family, corresponding document

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EUROPEAN SEARCH REPORT

Application Number
EP 16 19 0310

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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TECHNICAL FIELDS SEARCHED (IPC)

~~The present search report has been drawn up for all claims~~

Place of search	Date of completion of the search	Examiner
The Hague	12 July 2017	Post, Katharina

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X : particularly relevant if taken alone
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CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☒ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

1-12, 14, 15(completely); 13(partially)

☐ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

☐ The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).

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LACK OF UNITY OF INVENTION
SHEET B

Application Number
EP 16 19 0310

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-5, 7-12, 14, 15

   access control system according to claims 1 and 2, with a presence detector to selectively activate the radio interface; portable device according to claim 9; method according to claim 15

   ---

2. claim: 6

   access control system according to claim 6 with outside-area determination using the amplitude of the acoustic signal

   ---

3. claim: 13(partially)

   portable device according to claim 9 with an optical sensor , in response to output signals of which a user input confirmation can be requested

   ---

4. claim: 13(partially)

   portable device according to claim 9 with a user interface adapted to output operational information associated with the access control system if the device is positioned proximate the system for a predetermined time

   ---

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12-07-2017

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REFERENCES CITED IN THE DESCRIPTION

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- US 20160066254 A1 **[0004]**