

**A PERSONAL CRYPTOGRAPHIC KEY GENERATOR FOR USE IN A
COMPUTER IMPLEMENTABLE PROTOCOL FOR ESTABLISHING A
MOMENTARY TRUST ZONE**

5 FIELD OF INVENTION

The invention relates to network security at the point of contact and access, typically the login/password process, by human to digital system which includes both hardware and software. More particularly, the invention relates to the replacement of current
10 password part of the process that functioned as user authentication with the use of a hardware operation of personal cryptographic key generator, preferably a wirelessly charged battery powered card, as a root key to a series of cascading cryptographic authentication operations to establish a momentary trusted group of hardware and software during the login process and digital service operation procedure in the midst
15 of untrusted zone, spanning from end-user device to the entry point of the trusted zone managed by secured access management, combined with utilization of non-interactive Zero Knowledge Proof cryptographic primitive to authenticate the user to secured access management, the gatekeeper, of digital system.

20 BACKGROUND OF THE INVENTION

According to various cybersecurity reports, the user login processing channel remains a common entry point for hackers, with estimates ranging from 60-80% of attacks involving compromised passwords or credentials. This suggests that login attacks are
25 a significant entry point for attackers.

Other methods of attack may include network-based attacks such as phishing, malware, or other types of exploits, as well as email attacks that trick users into clicking on malicious links or downloading infected attachments. USB-based attacks

can also be a potential threat if an attacker gains physical access to a system or device and is able to plug in a USB drive that contains malware.

5 A wide arsenal of tools (predominantly software-based) and methods exists and are deployed to mitigate the above threats. Ironically, even these software-based tools have a similar user login process. Thus, they are exposed to similar threats and are as vulnerable as the systems they are designed and deployed to protect.

10 Therefore, when these systems that are protecting the protected systems are compromised but undetected, Zero-trust architecture has become an increasingly popular framework for securing systems and networks. The idea behind zero trust is simple: rather than assuming that all components within a system are trustworthy, the system should assume that no component can be trusted until proven otherwise. This means that every component, including applications, devices, and users, must be
15 repeatedly verified and authenticated before being granted access to resources or executing functions of process. However, current tools that configure and enforce Zero Trust operations are software based too, hence have similar vulnerabilities.

Current computing and networking domain

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The relationship between devices in the systems and networks are commonly based on client-server architecture used in current prevalent computer networking and distributed computing. In this model, a central server provides resources or services to multiple clients that connect to it over a network. In a client-server reference model,
25 there are typically two main components:

A) The client, which is a program or application overlaid by User Interface (UI) and User Experience (UX) that runs on the user's device (e.g. computer, smartphone, or tablet) and sends requests to the server. The User Interface (UI) refers to the visual

and interactive aspects of an application or website that users interact with directly. It includes elements such as buttons, menus, text fields, and graphics, as well as the layout, typography, and colour scheme of the user interface. For example, the login screen presented to the User with fields to key in required information such as login

5 ID and password. The User Experience (UX) refers to the overall experience that a user has when interacting with an application or website, including how easy it is to use, how efficient it is, and how enjoyable it is. UX design focuses on the user's needs, goals, and behaviour to create an interface that is intuitive, efficient, and satisfying to use. In other words, UI design is focused on creating an attractive and

10 functional visual interface that users can interact with, while UX design is focused on creating an experience that meets the user's needs and goals. These software runs on the device operating systems and communication functions.

B) The server, which is a program or application that runs on a central computer or

15 network device and responds to client requests by providing data, resources, or services. These components are connected by a network, such as the internet or a local area network (LAN). When the client needs to access a resource or service provided by the server, it sends a request over the network to the server. The server processes the request and sends a response back to the client. The client and server can be on

20 different physical machines, and the server may handle requests from multiple clients simultaneously. This allows for efficient resource sharing and scalability in large-scale systems.

The operation of the client-server model can be described as follows:

- 25 1. A client application running on a user's device (e.g. a computer, tablet, or smartphone) initiates a connection to a server application over a network.
2. The server application listens for incoming connections from clients and accepts the connection request from the client.
3. Once the connection is established, the client sends a request to the server to

perform a specific action, such as retrieving data or executing a function.

4. The server receives the request and processes it, using its available resources to generate a response.
5. The server sends the response back to the client over the network.
- 5 6. The client receives the response and takes the appropriate action based on the information received.
7. If necessary, the client may send additional requests to the server to complete a task or obtain more information.
8. Once the client is done with the server, it closes the connection.

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The client-server model is used in a wide range of applications, such as web servers, email servers, database servers, and game servers that constitutes the foundation of Digital Domain. It allows for efficient resource sharing and provides a scalable architecture that can accommodate large numbers of clients that serves the users

15 (Humans).

Log in page which is part of login process is normally the first User's touchpoint with the Digital Domain. The system login process typically involves the following steps:

1. The user navigates to the login page of the system they want to access.
- 20 2. The user enters their username or email address or service provider issued ID or government issued Digital ID and subsequent password into the appropriate fields on the login page.
3. The system checks the entered credentials against its database of authorized users to ensure that they are valid and match an existing user account.
- 25 4. If the credentials are valid, the system grants access to the user and directs them to the appropriate user interface. If the credentials are invalid, the system displays an error message and prompts the user to re-enter their credentials.
5. Depending on the system's security settings, the user may be prompted to provide additional authentication factors, such as a security question, biometric

authentication (e.g. fingerprint, facial recognition), or a one-time code sent to their mobile device.

6. Once the user is authenticated and authorized, they can access the features and functions of the system based on their permissions and privileges.

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It's worth noting that the login process may vary slightly depending on the system and its security policies. Some systems may also include additional steps or require specific authentication methods to ensure a high level of security.

10 However, despite this robust approach to security, there is still two common points of weakness that hackers can exploit: the human factor plus the more sophisticated UI/UX provides larger surface of attack. Whether it's through human weakness exploited by social engineering or malware installed within UI/UX operating with more complex local, remote cloud-based servers and security tools before and after
15 deployment, Therefore, the weakest link in any security system is often the user and end-user device (deemed in untrusted zone), particularly during login. The problem is that every security system has the same common point of vulnerability: the login process. As a result, even the most secure systems are only as strong as their weakest link, in particular, this weak link. The current method, mainly user focused, identity
20 and authentication methods of managing passwords and access controls relies on software-based systems that can themselves be hacked, thus, making it difficult to trust them to perform their role of protecting systems against software-based threats.

To strengthened User identity authentication, most financial related operation added
25 the use of one-time passwords (OTPs) as 2 Factor Authentication (2FA). Some deployed additional authentication methods called Multi-Factored Authentication (MFA). OTPs are unique codes generated for a single use are utilized as additional authentication of users when accessing a system or network. OTPs can be sent via SMS, email, or generated using mobile applications. While OTP is considered as a

stronger authentication method than static password, they are not completely immune to vulnerabilities. Various techniques exist frequently used by cybercriminals to remotely intercept, retrieve or acquire OTPs sent through SMS or email if these channels are not secure. For example: like any other security mechanism, OTPs are not fool proof and has been vulnerable to different types of attacks. Here are some examples of OTP hacks:

1. Social engineering: Attackers can trick the user into revealing the OTP by phishing or other social engineering techniques. For example, an attacker may send an email or SMS claiming to be from the user's bank or other trusted organization, and ask the user to provide the OTP for verification.
2. Man-in-the-middle attack: In a man-in-the-middle attack, the attacker intercepts the communication between the user and the server and can steal the OTP. This can be done by intercepting the SMS containing the OTP or by using a fake login page to capture the OTP entered by the user.
3. Brute force attack: A brute force attack is a trial-and-error method in which the attacker tries all possible combinations of the OTP until the correct one is found. This is difficult to do if the OTP has a long and complex combination of numbers, letters, and symbols.
4. OTP interception: An attacker can use malware or other techniques to intercept the OTP as it is generated on the user's device. This can be done by infecting the user's device with malware or by exploiting vulnerabilities in the device or the OTP generation process.
5. Pretexting: Pretexting involves the attacker impersonating the user or a trusted entity and requesting the OTP from the service provider. This can be done by using stolen credentials or other information to convince the service provider to provide the OTP.

The interception of OTPs can lead to severe consequences for the victim, as cybercriminals can assume easy access passage because all those institutions that

implemented OTP as THE final and decisive step of User authentication, they can gain unauthorized access to sensitive information or systems or services that require authentication. This access can result in a wide range of issues, including financial losses, data breaches, identity theft, operational disruption, loss of data integrity and other forms of cybercrime. For instance, if a cybercriminal intercepts an OTP used to authenticate online banking transactions, they can potentially make fraudulent transactions using the victim's account, leading to financial losses for the victim. Similarly, if the OTP is used to access confidential business information, the interception can lead to corporate espionage, loss of intellectual property, and damage to the organization's reputation. Moreover, cybercriminals can use the intercepted OTP to steal personal information, such as social security numbers, credit card numbers, and other sensitive information. This information can be used for identity theft, which can lead to long-lasting financial and legal consequences for the victim. In some cases, cybercriminals may even use the intercepted OTP to gain control of the victim's device or system, enabling them to conduct further attacks or to install malware that can cause even more damage.

Therefore, by adding another layer of authentication that is already hacked by many methods over the weak static password authentication method and regarded as the final pass have to be seriously reconsidered.

There are several alternative security methods to OTPs that can be used to protect sensitive information and prevent unauthorized access. One of them is biometric authentication, where a user's biometric data collected from their smartphone is compared to a template stored either on the mobile device or a cloud server. While biometric authentication on smartphones or servers offers several advantages, including convenience and enhanced security, it also has some drawbacks that need to be carefully considered. The potential risks of using biometric authentication on smartphones or servers include the multipurpose nature of smartphones that can

prompt hacking and the transmission of biometric data over insecure networks that can be intercepted.

A similar method of the biometric authentication can be found in US20030139984A1.

- 5 This Patent discloses a system and method that enables cashless and clerkless transactions to purchase a wide variety of products. The system is made up of four key functional components, including a point-of-sale terminal, identification devices, databases, and a network to link them. To carry out a cashless and clerkless transaction, the system collects information about the product, personal details, and
- 10 biometric information of the individual who wants to buy the product. This captured biometric information is matched against stored, typically in a centralized multiuser database not the point of usage, biometric data to verify the buyer's identity. If the buyer's identity is confirmed, the system permits the sale transaction and updates inventory and financial databases accordingly. Additionally, the system can be used to
- 15 confirm that the customer has legitimately purchased merchandise as they exit the store.

- Nevertheless, the biometric templates are stored on the server which leads to a potential loop hole where the transmission of biometric information can be
- 20 intercepted by cybercriminals if the network is not secure and compromising the user's biometric data. If the biometric data is stolen, it cannot be easily changed like a password, making it a significant risk for users. Furthermore, Biometric data is considered sensitive personal information and is subject to data privacy regulations, such as the Personal Data Protection Act (PDPA) in some countries. The PDPA
- 25 outlines strict guidelines for the collection, use, and disclosure of personal data, including biometric data. Therefore, any company or organization that collects, uses, or stores biometric data on a server must ensure that they comply with the PDPA or similar data privacy regulations to protect the privacy and security of their customers' personal information. Failure to do so can result in severe legal and financial

consequences, as well as damage to the company's reputation.

To address these challenges, a new approach is needed that complements Trusted Zone of Zero Trust Architecture with establishment of momentary trust in the Untrusted Zone of derives the security protocol based on Zero Trust of all related operating entities, that use dedicated hardware without operating system and normally offline and only online to transmit its generated ephemeral key as the root key for series of cascading authentication operations between neighbouring entities(hardware, software) resulting in Zero Knowledge Proof operation of User authentication without any subsequent need of key storage or recovery, hence reduce to the space for hacks via social engineering that exploit human weakness to the minimum. This hardware-rooted authentication protocol provides a stronger layer of protection against unauthorized access and breaches without any further reading or keying in of any secret codes by the User. By moving away from layers of software only-based security operations, organizations can better protect their systems and networks from attacks that exploit the human factor. This invention provides such a method and system thereof.

SUMMARY OF INVENTION

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In a first aspect of the invention, there is provided a computer implementable protocol for establishing a momentary trust zone as part of a procedure, comprising the steps of: receiving, by a user interface, an input of a onboarded user to initiate the procedure; instructing, by the user interface, the onboarded user to be biometrically authenticated to then activate a personal cryptographic key generator; performing, by the personal cryptographic key generator, an ephemeral key generation and/or credentials signing upon activation by the onboarded user; transmitting, by the personal cryptographic key generator, the newly generated ephemeral keys and/or signed credentials to a cryptographic processor which is embedded within the user

interface; processing, by the cryptographic processor, data received from the user interface and the personal cryptographic key generator; and transmitting, by the cryptographic processor, the processed data to a verification processor which is embedded within the service provider servers; whereby the momentary trust zone is

5 established when the processed data is authenticated and verified by the verification processor; wherein the procedure includes a user on boarding process, a user login process, an operation process, or any combination thereof; wherein the personal cryptographic key generator is configured to: (a) operate entirely in an offline mode with the exception of a single instance where the personal cryptographic key

10 generator is switched to an online mode to transmit the generated ephemeral keys and/or the signed credentials, and after which it switches back to the offline mode; and (b) operate in an unbalance communication mode where the personal cryptographic key generator exclusively initiates and/or disconnects a data transfer link to a device which the user interface is operated thereon; wherein the

15 cryptographic processor is configured to (a) perform an encryption and/or decryption on the received data to ensure data confidentiality, (b) perform a data integrity checking algorithm on the received data, and (c) perform signatures signing on the user interface credential to authenticate and verify the user interface; and wherein the personal cryptographic key generator is a battery powered device. Its form can be

20 card, capsule, band, key chain or any other form that is practical and convenient for user and having one or more input modules to which the user can interact therewith for the activation of the personal cryptographic key generator, and a vibration module configured to vibrate the one or more input modules or at least one section of the wirelessly charged battery powered card using a vibration pattern selected from a

25 plurality of pre-stored vibration patterns based on predetermined conditions when the user interacts with the one or more input modules.

In this aspect of the invention, the protocol, during the user onboarding process, may comprise the steps of: retrieving, by the cryptographic processor, a signed certificate

from a certificate authority server; receiving, by the user interface, a unique identity of the personal cryptographic key generator to verify with a device registry server; registering, by the cryptographic processor, the user interface signed credential verification key; instructing, by the user interface, the user to activate the personal
5 cryptographic key generator; performing, by the personal cryptographic key generator, an ephemeral key generation and/or credentials signing upon activation by the user; transmitting, by the personal cryptographic key generator, the generated ephemeral keys and/or signed credentials to the cryptographic processor; forwarding, by the cryptographic processor, a verification key of the personal cryptographic key
10 generator to the verification processor; and binding, by the verification processor, the verification key with the user's profiles.

In this aspect of the invention, the protocol, during the operation process, may comprise the steps of: providing, by the user interface, functional options for the user
15 to select and execute upon successful establishment of the momentary trusted zone; instructing, by the cryptographic processor, the user interface to request for activating the personal cryptographic key generator upon receiving one or more instruction messages of the function options which required signatures from the user interface; instructing, by the user interface, the user to activate the personal cryptographic key
20 generator; performing, by the personal cryptographic key generator, an ephemeral key generation and/or credentials signing upon activation by the user; transmitting, by the personal cryptographic key generator, the newly generated ephemeral keys and/or signed credentials to the cryptographic processor; performing, by the cryptographic processor, signature signing on the instruction messages; and transmitting, by the
25 cryptographic processor, the signed instruction messages, the signed credential, and a newly generated verification key to the verification processor.

In this aspect of the invention, the personal cryptographic key generator may comprise a physical isolation arrangement for protecting it physically against

unauthorised access and a counterparty cryptography processor to establish the data transfer link in a secure fashion via one or more cryptographic protocols.

In this aspect of the invention, the personal cryptographic key generator may
5 comprise a notifier to provide a notification of a current operation status.

In this aspect of the invention, the one or more input modules may be in the form of one or more biometric sensors for capturing biometric traits of a user and a processor for verifying an identity of the user using an in-device hardware secure memory
10 stored template and/or template-free Artificial Intelligent driven biometric authentication method, whereby the ephemeral keys and credentials are respectively generated and signed upon successful verification of the user.

In this aspect of the invention, the one or more input modules may be in the form of
15 one or more mechanical or electric actuators for receiving inputs from the user.

In this aspect of the invention, the vibration module may be a piezoelectric vibrator or electro-magnetic actuators.

20 In this aspect of the invention, the piezoelectric vibrator or electro-magnetic actuators may be stacked with the one or more input modules.

In this aspect of the invention, the piezoelectric vibrator or electro-magnetic actuators may be arranged to partially or entirely surround the one or more input modules.
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In this aspect of the invention, the generated ephemeral keys and/or signed credentials may be of a predetermined structure and size for them to be transmitted in a consistent and secure manner.

In this aspect of the invention, the credential may be signed using one or more Digital Signature Algorithms.

In this aspect of the invention, the personal cryptographic key generator may
5 comprise a QR code that contains the unique identity of the personal cryptographic key generator, and the unique identity is retrievable through scanning the QR code.

In this aspect of the invention, when onboarding user with Digital Identity, the personal cryptographic key generator's hardware secured memory custodies and
10 protect user's Digital Identity.

In this aspect of the invention, the cryptographic processor (30) may be configured to perform a cascading signature operation that signs a batch of instruction messages.

15 In a second aspect of the invention, there is provided a personal cryptographic key generator in the form of a battery powered card, as an example, comprises a card body; one or more input modules to which an user can biometrically authenticated and interact therewith for activating the personal cryptographic key generator; a vibration module configured to vibrate the one or more input modules or at least one
20 section of the card body; a transmission module for establishing a data transfer link to connect with a device which the user interface is operated thereon via a communication protocol; a battery for supply electricity to components of the personal cryptographic key generator; and a processing unit connected to the one or more input modules, the vibration module, the transmission module, and the battery;
25 wherein the processing unit is configured to: (a) generate ephemeral keys and sign credentials upon the user activates the personal cryptographic key generator via the one or more input modules; (b) instruct the vibration module to perform a vibration pattern selected from a plurality of pre-stored vibration patterns based on predetermined conditions when the user interacts with the one or more input modules;

- (c) operate the cryptographic key generator entirely in an offline mode with the exception of a single instance where the personal cryptographic key generator is switched to an online mode to transmit the generated ephemeral keys and/or the signed credentials, and after which it switches back to the offline mode; and (d)
- 5 operate in an unbalance communication mode where the personal cryptographic key generator exclusively initiates and/or disconnects the data transfer link.

In this aspect of the invention, the one or more input modules may be in the form of one or more biometric sensors for capturing biometric traits of a user and a processor

10 for verifying an identity of the user using an in-device hardware secure memory stored template and/or template-free Artificial Intelligent driven biometric authentication method, whereby the ephemeral keys and credentials are respectively generated and signed upon successful verification of the user.

- 15 In this aspect of the invention, the one or more input modules may be in the form of one or more mechanical or electric actuators for receiving inputs from the user.

In this aspect of the invention, the vibration module may be a piezoelectric vibrator.

- 20 In this aspect of the invention, the piezoelectric vibrator may be stacked with the one or more input modules.

In this aspect of the invention, the piezoelectric vibrator may be arranged to partially or entirely surround the one or more input modules.

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In this aspect of the invention, the card body comprises a QR code that contains the unique identity of the personal cryptographic key generator (10), and the unique identity is retrievable through scanning the QR code.

One skilled in the art will readily appreciate that the invention is well adapted to carry out the objects and obtain the ends and advantages mentioned, as well as those inherent therein. The embodiments described herein are not intended as limitations on the scope of the invention.

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BRIEF DESCRIPTION OF THE DRAWINGS

For the purpose of facilitating an understanding of the invention, there is illustrated in the accompanying drawing the preferred embodiments from an inspection of which
10 when considered in connection with the following description, the invention, its construction and operation and many of its advantages would be readily understood and appreciated.

Fig. 1 is a schematic diagram illustrating a general architecture of a system
15 for establishing a momentary trusted zone during a login and operation procedure.

Fig. 2 is a schematic diagram illustrating a user onboarding process.

20 Fig. 3 is a schematic diagram illustrating a user login process.

Fig. 4 is a schematic diagram illustrating an operation process.

Fig. 5 is a block diagram illustrating a personal cryptographic key generator
25 in the form of a wirelessly charged battery powered card.

Fig. 6 is a high-level schematic diagram illustrating a specific architecture of the wirelessly charged battery powered card.

DETAILED DESCRIPTION OF THE INVENTION

It will be understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer program instructions. These computer program instructions may be provided to a processor of a general-purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, that execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

These computer program instructions may also be stored in a computer-readable memory that can direct a computer or other programmable data processing apparatus to function in a particular manner, such that the instructions stored in the computer-readable memory produce an article of manufacture including instruction means that implement the function/act specified in the flowchart and/or block diagram block or blocks.

The computer program instructions may also be loaded onto a computer or other programmable data processing apparatus to cause a series of operational steps to be performed on the computer or other programmable apparatus to produce a computer implemented process such that the instructions that execute on the computer or other programmable apparatus provide steps for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

The invention will now be described in greater detail, by way of example, with reference to the drawings.

Referring to **Fig. 1**, a system for establishing a momentary trust zone as part of a login and operation procedure is illustrated. The system can be divided into two planes, namely the management plane and the login authentication plane. A device registry server **50** and a certificate authority server **60** are part of the management plane and are preferably being managed under a zero-trust zone environment. By managing these servers in the zero-trust environment, an access to these servers **50, 60** is restricted, and all attempts to access them are subject to strict authentication and authorization procedures. Additionally, any communication with these servers **50, 60** is encrypted to ensure the confidentiality of the data being transmitted. Under the login authentication plane, the components can be divided into a user end, an untrusted zone and trusted zone. The user end comprises a personal cryptographic key generator **10**, the untrust zone comprises a user interface **20** with a cryptographic processor **30** embedded therewithin, and the trusted zone comprises one or more service provider servers with a user database and a verification processor **40** embedded therewithin.

The personal cryptographic key generator **10** is a physical device that can be easily carried around with and safely kept by the user. Preferably, the personal cryptographic key generator **10** has zero software and all functions of the personal cryptographic key generator **10** are carried out by dedicated hardware modules so that malwares cannot be deposited into the personal cryptographic key generator **10**. As a result, the risk of malware or other software-based attacks can be prevented. The personal cryptographic key generator **10** can take various forms including but is not limited to physical token device, wirelessly charged battery powered cards or any personal objects which can be embedded with integrated circuits. By way of example, the personal cryptographic key generator **10** can be provided with a casing that has a physical isolation arrangement for protecting it physically against unauthorised access. A QR code can be printed on an exposing surface of the personal cryptographic key generator **10**. Such QR code contains a unique identity of the

personal cryptographic key generator **10**, and the unique identity is retrievable through scanning the QR code. Alternatively, the personal cryptographic key generator **10** can be provided with a notifier to provide a notification of a current operation status. Such notification may include but is not limited to audio notification,
5 visual notification, tactile notification and dashboard notification.

The personal cryptographic key generator **10** is designed specifically to generate ephemeral keys and sign credentials. The ephemeral keys are cryptographic keys that are generated for a short period of time and then discarded or destroyed. Since these
10 keys are only used for a short period of time, even if they are intercepted, they cannot be used to decrypt data from other sessions or messages. Preferably, the ephemeral keys may include a signature key and a verification key. The signature key can be used to digitally sign credentials or messages for ensuring that the credentials or messages have not been tampered with during transmission. The verification key can
15 then be used to check the integrity of the signed credentials or messages so as to ensure that the signed credentials or messages were not modified or forged. The generated ephemeral keys and signed credentials are configured to be transmitted in a consistent and secure manner, with a predetermined structure and size. This is important for ensuring that the keys and credentials can be transmitted and processed
20 efficiently, and that they cannot be intercepted or modified by an attacker during transmission.

In the process of credential signing, the credentials are first hashed to create a unique and irreversible string of characters. These hashed credentials are then encrypted to
25 protect it from unauthorized access, and the resulting encrypted string is signed by digital signature algorithm to provide additional authentication and verification. By using this combination of hashing, encryption, and signed credentials, the system can ensure that only authorized users are granted access to the signed credential. The hashed and encrypted signed credential acts as the foundation or root of the

authentication process, providing a secure and reliable method for verifying the identity of the user.

The personal cryptographic key generator **10** is provided with a transmission module
5 that establish a data transfer link with a device which the user interface is operated
thereon. Specifically, the personal cryptographic key generator **10** is configured to
establish the data transfer link to connect with the cryptographic processor **30** via a
communication protocol. Such communication protocols may include but is not
limited to short-range wireless communication protocols such as Bluetooth, WiFi,
10 Near Field Communication, ZigBee, Z-Wave, IrDA, ANT, RFID or any combination
thereof. It is important that the personal cryptographic key generator **10** is configured
to operate entirely in an offline mode with the exception of a single instance where
the personal cryptographic key generator **10** is switched to an online mode, which the
data transfer link is established, to transmit the generated ephemeral keys and/or the
15 signed credentials, and after which the personal cryptographic key generator **10**
switches back to the offline mode. By keeping the personal cryptographic key
generator **10** in the offline mode, it reduces the attack surface and potential
vulnerabilities that could be exploited by attackers to steal or manipulate the
ephemeral keys and signed credentials. Furthermore, the personal cryptographic key
20 generator **10** also operates in an unbalance communication mode where the personal
cryptographic key generator **10** exclusively initiates and/or disconnects the data
transfer link. The unbalance communication mode allows the personal cryptographic
key generator **10** to determine when and how data is transmitted. In addition to that,
the transmission module may further comprise a counterparty cryptography processor
25 to ensure the operations of the personal cryptographic key generator **10** are performed
securely and cannot be intercepted or compromised. The counterparty cryptography
processor is mainly used in the setup phrase of every communication link between the
personal cryptographic key generator **10** and the cryptographic processor **30** to verify
identities and provide protection for the personal cryptographic key generator **10** from

unauthorized access or interception.

Preferably, the personal cryptographic key generator **10** may comprise one or more input means for receiving input data from the user. The operations of generating the
5 ephemeral keys and signing credentials can then be activated upon receiving the input data from the user. Such input means may include but is not limited to physical buttons, touch screen, accelerometer, camera, microphone, scanner, and biometric sensor. By way of example, the personal cryptographic key generator **10** includes a biometric sensor as the input means to capture biometric traits of the user. In this
10 example, the personal cryptographic key generator may further comprise a processor for verifying an identity of the user using an in-device hardware secure memory stored template and/or template-free biometric authentication algorithm. Upon successful verification of the user, the personal cryptographic key generator **10** will then generate and sign the ephemeral keys and credentials respectively. Preferably, the
15 in-device hardware secure memory stored template and/or template-free biometric authentication analyzes raw biometric data captured from the user during the authentication process and use machine learning algorithms or deep learning techniques to analyze the biometric traits and determine whether they match previous instances of the same trait that were previously captured from the same user.

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Preferably, the personal cryptographic key generator **10** can include a battery that is chargeable wirelessly designed to mitigate against well-known hacks via physical connections of both Data and power channels. It should be understood that the charging port may change as technology advances. Different power modes can be
25 implemented by either the power supply or the processor to optimize power consumption and extend the battery life. Preferably, the power modes may include an active mode where all components of the personal cryptographic key generator **10** are fully powered or operated at full capacity, and a sleep mode where some components are disabled or power supply to those components are being reduced/minimized. By

way of example, the personal cryptographic key generator **10** may switch to the active mode when a present of biometric is detected by the biometric sensor and switch to the sleep mode after the generated ephemeral keys and/or the signed credentials are transmitted to the cryptographic processor.

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Referring to **Fig. 5**, an example of the personal cryptographic key generator **10** is illustrated. In this example, the personal cryptographic key generator **10** takes the form of a wirelessly charged battery powered card comprises a card body **11**, one or more input modules **12**, a vibration module **13**, a transmission module **14**, a battery **15**,
 10 and a processing unit **16**. In this embodiment, it eliminates the need for users to carry an additional device beyond their usual possessions. In addition to the conventional scan and pay method, the user may be required to press the touch button which is also a liveness test and then biometrically authenticate their identity via the input modules **12** before the completion of the transaction.

15

Preferably, the card body **11** is a durable and compact substrate that encapsulates the components of the personal cryptographic key generator **10**. The card body **11** serves as the physical framework for the components of the personal cryptographic key generator **10**, ensuring secure integration and protection for the components. The card
 20 body **11** can be made of a resin material which includes but not limited to polyvinyl chloride, polycarbonate, polyethylene terephthalate glycol, acrylonitrile butadiene styrene, polyethylene, polyester or any combination thereof. Alternatively, the card body **11** can comprise a QR code that contains the unique identity of the personal cryptographic key generator **10**, and the unique identity is retrievable through
 25 scanning the QR code.

The one or more input modules **12** allow the user to interact with it for activating the personal cryptographic key generator **10**. Preferably, the one or more input modules **12** include one or more mechanical or electric actuators such as tactile buttons for

traditional user interaction. Alternatively, the buttons may be virtual buttons provided by a touch screen. In the preferred embodiment, the one or more input modules **12** further comprise one or more biometric sensors for capturing biometric traits of a user and a processor for verifying an identity of the user using an in-device hardware secure memory stored template and/or template-free Artificial Intelligent driven biometric authentication method, whereby the ephemeral keys and credentials are respectively generated and signed upon successful verification of the user.

The vibration module **13** is configured to vibrate the one or more input modules **12** or at least one section of the card body **11** with at least one vibration pattern selected from a plurality of pre-stored vibration patterns based on predetermined conditions when the user interacts with the one or more input modules **12**. Preferably, the vibration module is a piezoelectric vibrator that can be arranged to stack with the one or more input modules **12** or to partially or entirely surround the one or more input modules **12**. By way of example, the predetermined conditions may include a vibration pattern that provide one-time tactile feedback indicating a successful verification of the user during the biometric authentication process. In another example, the predetermined conditions may include a vibration pattern that provide two-time tactile feedback indicating a failed verification of the user during the biometric authentication process. Yet in another example, the predetermined conditions may include a vibration pattern that provide a few seconds long tactile feedback indicating a successful activation of the personal cryptographic key generator **10**. For individuals with visual challenges, the vibration patterns generated by the vibration module as a feedback mechanism, allowing them to discern the outcome of their interaction with the one or more input modules **12**. This provides a practical solution for blind users who may rely on distinct vibration patterns to interpret pressing results and operation status, thereby enhancing the overall user experience and usability of the personal cryptographic key generator **10** for individuals with diverse accessibility requirements.

The transmission module **14** and the battery **15** can function similarly or the same, as discussed earlier.

- 5 The processing unit **16** is preferably a microcontroller or an integrated circuit chip that connects to the different components **12-15** of the wirelessly charged battery powered card for managing and controlling the operations of the different components **12-15**. The processing unit **16** can be provided with a data storage for pre-storing a plurality of computer implementable instructions. Such instructions may include but
- 10 are not limited to: (a) generating ephemeral keys and signing credentials upon the user activating the personal cryptographic key generator **10** via the one or more input modules **12**; (b) instructing the vibration module **13** to perform a vibration pattern selected from a plurality of pre-stored vibration patterns based on predetermined conditions when the user interacts with the one or more input modules **12**; (c)
- 15 operating the cryptographic key generator **10** entirely in an offline mode with the exception of a single instance where the personal cryptographic key generator **10** is switched to an online mode to transmit the generated ephemeral keys and/or the signed credentials, and after which it switches back to the offline mode; and (d) operating in an unbalanced communication mode where the personal cryptographic
- 20 key generator **10** exclusively initiates and/or disconnects the data transfer link.

Referring to **Fig. 6**, a specific example of the personal cryptographic key generator in the form of the wirelessly charged battery powered card is illustrated. Preferably, the wirelessly charged battery powered card comprises a microcontroller unit **21**, a

- 25 wireless communication module **22**, a biometric scanner **23**, a piezoelectric actuator **24**, one or more indicators **25**, a power storage **26**, wirelessly charging modules **27, 28** and a liveness test switch **29**. The microcontroller unit **21** is an intelligent semiconductor integrated circuit that comprises a processor unit, memory modules, communication interfaces and peripherals. It is responsible for processing and

executing cryptographic primitive algorithms, managing data storage, and controlling the overall operation of the wirelessly charged battery powered card **20**. The tamperproof nature of the personal cryptographic key generator allows the microcontroller unit **21** to initiate its boot process in a secure manner, to ensure all subsequent operations and code execution occur within a secure environment, and to ensure data is securely stored in its memory. The microcontroller unit **21** can be integrated with hardware components to accelerate cryptographic operations, such as encryption, hashing, and digital signature so that the performance and efficiency of the cryptographic operation can be enhanced while maintaining a high level of security. Preferably, the wireless communication module **22** is a Bluetooth module to enable secure communicate with the user interface **20** using a Bluetooth protocol. The biometric scanner **23** is preferably a fingerprint sensor for capturing fingerprints of the user and transmitted directly to the microcontroller unit for the authentication and verification process to take place in secured execution zone. The piezoelectric actuator **24** is preferably a tactile feedback- piezo haptic configured to provide at least one vibration pattern selected from a plurality of pre-stored vibration patterns based on predetermined conditions when the user interacts with the biometric scanner **23** or any other input modules. The indicators **25**, which may include LEDs or display screens, provide visual feedback to the user, indicating the status of the wirelessly charged battery powered card. Preferably, the power storage **26** is an ultra-thin rechargeable battery that store electrical energy to power the operations of the card. The wireless charging modules **27, 28** comprises a coil or antenna **28** for capturing the electromagnetic field generated by external transmitter and a rectifier and control circuitry **27** for converting the current induced in the coil or antenna **28** into a current voltage suitable for charging the power storage **26**. This setup is designed for energy harvesting only without any passage for incoming data transfer to reduce surface of attack. The liveness test switch **29** is used to verifies the user's presence or "liveness" during biometric authentication processes, preventing spoofing or unauthorized access attempts.

The user interface **20** can be located on either the client device or the service provider's servers. A client device is a type of computer hardware that accesses the service provider servers via a network communication. Examples of the client device may include but is not limited to portable media player, cellular telephone, pocket-sized personal computer, personal digital assistants ("PDAs"), smartphone, desktop computer, laptop computer, and tablet computer. The client device may also include control circuitry, storage, memory, communications circuitry, input and/or output interfaces as well as any of the additional features. The network communication can be a wireless network connection established via a wireless protocol cloud such as Long-Term Evolution (LTE) cloud, Code Division Multiple Access (CDMA) and its derivatives, Enhanced Data Rates for GSM Evolution (EDGE), 3G protocol, High Speed Packet Access (HSPA), 4G protocol, 5G protocol and the like, in accordance to the advancement of wireless technology with time. The network communication can also be a wired network in which the communication is established through a local network port.

Depending on the setup, the user interface **20** may be in the form of a web browser application hosted by the service provider servers or a dedicated software application that is installed on the client device. The user interface **20** allows users to interact with the service provider servers to complete the login and operation procedures. The interaction may include but not limited to receive input from, and display output to, the user. The user interface **20** may be integrated with a plurality of buttons, icons, or widgets and being arranged in a manner where the users can easily access to the operations provided by the service provider servers. Each button, icon, or widget can be linked to their designated module for commencing their designated operations.

The cryptographic processor **30** is a specialized component that is embedded within the user interface **20**. If the user interface **20** is in the form of a software application

installed on the client device, then the cryptographic processor **30** will also be installed on the client device as a separate component. On the other hand, the cryptographic processor **30** may also be embedded within the service providers' servers, particularly when the user interface **20** is accessed through a web browser application hosted by the service provider servers. Preferably, the cryptographic processor **30** is whitelisted on the certificate authority server **60** to ensure that only authenticated and authorized application can access the service provider servers.

At most times, the cryptographic processor **30** remains in a dormant state until it receives instructions or calls from the user interface **20** or the software application. The cryptographic processor **30** then challenges and verifies the authenticity of the instructions from the user interface **20** or the software application before triggering an instruction to the user interface **20** or the software application to visually or by audio request for the ephemeral keys or the signed credential from the personal cryptographic key generator **10**. In one embodiment, the cryptographic processor **30** can be configured to operate with more than one user interfaces **20** or software applications. Using a single cryptographic processor **30** to operate multiple applications is a cost-effective and efficient approach that can improve system performance, reduce power consumption, and simplify maintenance. With a single cryptographic processor **30**, resources can be allocated efficiently between different applications, providing greater flexibility to switch between them as per the user's requirement. This approach reduces the complexity of the system, making it easier to maintain and troubleshoot in case of any issues. Once the personal cryptographic key generator **10** generates the ephemeral keys and transmits to the cryptographic processor **30**, the cryptographic processor **30** then performs multiple cycles of salted hash and cryptographic signature operations, using appropriate cryptographic primitives that meet the required levels of complexity and latency. The cryptographic processor **30** will then send the final signed credential to the associated verification processor **40**. The cryptographic processor **30** also signs individual or batched lots of

instructions, contents such as JSON Certificates, datasets, documents, audio and video files, and sends them to the relevant verification processor **40** at the server provider services. The cryptographic processor **30** may also communicate with the verification processor **40** via encrypted and authenticated channels, and performs the slave role in
 5 unbalanced communication mode of the personal cryptographic key generator **10**.

Preferably, the service provider servers are operated by one or more service providers. The service providers generally fall into spectrum of categories based on the following impact considerations: 1) Availability, 2) Severity, 3) Sensitivity normally
 10 rated as Low, Medium, High, Critical or rated by a weighted graphical scale. Therefore, if a service provider's impact levels of all 3 considerations are Low, then they can deploy adequate minimum level of security defence. However, if a service provider's impact levels of all 3 considerations have one or more Medium, then they have to balance their mitigation levels with acceptable convenience and cost.
 15 Finally, if a service provider's impact levels of all 3 considerations have one or more are High and/or Critical, then it is imperative that they deploy highest level of security strategy that match their Risk management requirements. Examples of such Service Providers can be financial institutions or government institutions. The financial institutions may include but are not limited to commercial banks, investment banks,
 20 credit unions, insurance companies, and brokerage firms. The government institutions may include but are not limited to legislative bodies, central banks, regulatory agencies, and public service agencies. Depending on the nature of the service providers, the services offered by the different service providers may vary. It should be noted that some functions of the service provider servers can be easily carried out
 25 by the software application due to the advancement of technology. Therefore, the service provides servers can be categorised into local servers or remote servers but they are assumed to be trusted as they are whitelisted with the certification authority server **60**. Preferably, the user database is managed by the service provider server as the user database contains information about the user including the user personal

details, account information, transaction history and other sensitive information. Further information relating to the generated ephemeral keys and signed credentials by the personal cryptographic key generator **10**, and signed credentials and instructions from the cryptographic processor **30** are also stored in the user database.

- 5 Such further information will be paired with user information of that particular user.

The verification processor **40** is embedded within the service provider servers and it is designed to work in tandem with the cryptographic processor **30**. In general, the verification processor **40** retrieves the verification key from the user database or
 10 initiate an insertion process to insert the verification key into the user database during a user onboarding process. The verification processor **40** remains idle until a service request is received from the cryptographic processor **30**. Upon receiving the request, the verification processor **40** then retrieves the relevant keys from the user database and processes it with an algorithm to generate the appropriate single-use verification
 15 key to verify the signature of signed credential received from the cryptographic processor **30**.

The device registry server **50** is responsible for the management and verification of the personal cryptographic key generator device **10**. The device registry server **50**
 20 functions as the custodian of the personal cryptographic key generator **10** certificates and it contains the unique identity of the personal cryptographic key generator **10**. During the user onboarding process, the device registry server **50** verifies the personal cryptographic key generator **10** of each new user to ensure that it is valid. This helps to prevent fraudulent use of the personal cryptographic key generator **10** and ensures
 25 that the genuine personal cryptographic key generator **10** are used by all users are properly authenticated before gaining access to the service operations provided by the service provider servers.

The certificate authority server **60** is responsible for issuing digital certificates that are

used to authenticate the user interface **20** or the software application installed on the client device. These digital certificates contain information about the user interface **20** or the software application. In addition, the certificate authority server **60** also manages the lifecycle of the digital certificates, including renewals and revocations.

- 5 The certificate authority server **60** will be provision with interfaces to Digital Identity systems (Officially operated by Governments or private service providers) based on conventional systems and/or decentralized distributed ledgers systems such as blockchain that binds Digital Identities with Device Digital Certificates and to further perform Digital Identity attestation service.

10

The login and operation procedure typically includes three stages: a user onboarding process, a user login process, and an operational process. The computer-implemented protocol for establishing a momentary trust zone may differ between the different stages of the login and operation procedure.

15

Referring to **Fig. 2**, the user onboarding process of the login and operation procedure is illustrated. In the first step, after successful download and installation of the software application, the user interface **20** or the software application connects to the embedded cryptographic processor **30**, the cryptographic processor **30** then connects
 20 to the certificate authority server **60** to obtain a signed certificate. In the second step, the QR code of the personal cryptographic key generator **10** is scanned to obtain the unique identity of the personal cryptographic key generator **10**. The cryptographic processor **30** then forwards the unique identity to the device registry server **50** for verifying the personal cryptographic key generator **10**. In the third step, the
 25 cryptographic processor **30** registers the user interface **20** or the software application's signed credential verification key. In the fourth step, the user interface **20** instructs the user to activate the personal cryptographic key generator **10**. Upon activation, the personal cryptographic key generator **10** generates the ephemeral keys and/or signs the credentials. Followed by transmitting the generated ephemeral keys and/or the

signed credentials to the cryptographic processor **30**. In the fifth step, the cryptographic processor **30** forwards generated ephemeral keys and/or the signed credentials to the verification processor **40**. In the sixth step, the verification processor **40** verifies the received data and then executes an insertion of the verification key that
 5 binds with that particular user profile (including Digital Identity).

Referring to **Fig. 3**, the user login process of the login and operation procedure is illustrated. In the first step, the user interface **20** receives login credential of the user to initiate the user login process. Typical legacy login credential may include user
 10 account ID and password but with this new process, only User Account ID or Digital ID is requested to be entered and verified. Upon positive verification, the user interface **20** then displays an instruction to prompt the user to activate the personal cryptographic key generator **10**. In the second step, the user activates the personal cryptographic key generator **10** to generate the ephemeral keys and/or sign the
 15 credentials. The activation can be triggered by a simple button press on the liveness test sensor of the personal cryptographic key generator. Subsequently, the user scans their biometrics on the biometric sensor of the personal cryptographic key generator **10** and thereby generating the ephemeral keys and/or credential signing upon successful authentication and verification of the user. Followed by transmitting the
 20 generated ephemeral keys and/or the signed credentials to the cryptographic processor **30**. In the third step, the cryptographic processor **30** processes the data received from the user interface **20** and the personal cryptographic key generator **10**. Such processing involves cryptographic processor **30** perform multiple cycles of Salted Hash and cryptographic signature operations done by combinations of appropriate
 25 cryptographic primitives that meets the required levels of complexity and latency with the ephemeral keys. In the fourth step, the cryptographic processor **30** transmits the processed data to the verification processor **40**. In the fifth step, the verification processor **40** retrieves the relevant keys of that particular user from the user database and processes it with an algorithm to generate the appropriate single-use verification

key to verify the signature of signed data received from the cryptographic processor **30**. The momentary trust zone is established when the processed data is authenticated and verified by the verification processor **40**. Once the momentary trust zone is established and user authentication completed with non-interactive Zero Knowledge Proof cryptographic primitive, the user interface **20** or the software application can then access to the functional operations provided by the service provider servers.

Referring to **Fig. 4**, the operation process of the login and operation procedure is illustrated. In the first step, the user interface **20** or the software application provides functional options for the user to select and execute upon successful establishment of the momentary trusted zone established and user authentication completed with non-interactive Zero Knowledge Proof cryptographic primitive. This part of the operation can be configured for single function operation or a batch of multiple functions to be collectively signed. In the second step, the cryptographic processor **30** instructs the user interface to request for activating the personal cryptographic key generator **10** upon receiving one or more instruction messages of the function options which required signatures from the user interface **20**. In the third step, the user activates the personal cryptographic key generator **10** to generate the ephemeral keys and/or sign the credentials. Followed by transmitting the generated ephemeral keys and/or the signed credentials to the cryptographic processor **30**. Preferably, new ephemeral keys are generated by personal cryptographic key generator **10** for each signing operation and transmits to the cryptographic processor **30**. In the fourth step, the cryptographic processor **30** performs signature signing on the instruction messages. If the operation is configured for batch signing, then the cryptographic processor **30** performs cascading signature operation to sign a batch of instruction messages. In the fifth step, the cryptographic processor **30** transmits the signed instruction messages, the signature, and a newly generated verification key to the service provider servers. By way of example, the operation process can be further used to conduct signing of digital documents such as contracts, invoices, financial statements, intellectual

property documents, HR documents, medical records, legal documents, government forms, academic transcripts, real estate documents, e-commerce transactions, cryptographic transactions as Smart Contracts, DeFi, and Web 3, NFT and any other future cryptographic based derivatives.

5

The present disclosure includes as contained in the appended claims, as well as that of the foregoing description. Although this invention has been described in its preferred form with a degree of particularity, it is understood that the present disclosure of the preferred form has been made only by way of example and that numerous changes in
10 the details of construction and the combination and arrangements of parts may be resorted to without departing from the scope of the invention.

CLAIMS

1. A computer implementable protocol for establishing a momentary trust zone as part of a procedure, comprising the steps of:
 - 5 receiving, by a user interface (20), an input of a user to initiate the procedure;
 - instructing, by the user interface (20), the user to activate a personal cryptographic key generator (10);
 - performing, by the personal cryptographic key generator (10), an ephemeral key generation and/or credentials signing upon activation by the user;
 - 10 transmitting, by the personal cryptographic key generator (10), newly generated ephemeral keys and/or signed credentials to a cryptographic processor (30) which is embedded within the user interface (20);
 - processing, by the cryptographic processor (30), data received from the user interface (20) and the personal cryptographic key generator (10); and
 - 15 transmitting, by the cryptographic processor (30), the processed data to a verification processor (40) which is embedded within service provider servers;
 - whereby the momentary trust zone is established when the processed data is authenticated and verified by the verification processor (40) with non-interactive Zero Knowledge Proof cryptographic primitive;
 - 20 wherein the procedure includes a user on boarding process, a user login process, an operation process, or any combination thereof;
 - wherein the personal cryptographic key generator (10) is configured to: (a) operate entirely in an offline mode with the exception of a single instance where the personal cryptographic key generator (10) is switched to an online mode in which a data
 - 25 transfer link is established to transmit the generated ephemeral keys and/or the signed credentials, and after which it switches back to the offline mode; and (b) operate in an unbalance communication mode where the personal cryptographic key generator (10) exclusively initiates and/or disconnects the data transfer link to a device which the user interface (20) is operated thereon;

wherein the cryptographic processor (30) is configured to (a) perform an encryption and/or decryption on the received data to ensure data confidentiality, (b) perform a data integrity checking algorithm on the received data, and (c) perform signatures signing on the user interface credential to authenticate and verify the user interface

5 (20); and

wherein the personal cryptographic key generator (10) is a wirelessly charged battery powered card having one or more input modules (12) to which the user can interact therewith for the activation of the personal cryptographic key generator (10), and a vibration module (13) configured to vibrate the one or more input modules (12) or at
10 least one section of the wirelessly charged battery powered card using a vibration pattern selected from a plurality of pre-stored vibration patterns based on predetermined conditions when the user interacts with the one or more input modules (12).

15 2. The computer implementable protocol according to claim 1, wherein the protocol, during the user onboarding process, comprises the steps of:

retrieving, by the cryptographic processor (30), a signed certificate from a certificate authority server (60);

receiving, by the user interface (20), a unique identity of the personal cryptographic
20 key generator (10) to verify with a device registry server (50);

registering, by the cryptographic processor (30), the user interface' (20) signed credential verification key;

instructing, by the user interface (20), the user to activate the personal cryptographic key generator (10);

25 performing, by the personal cryptographic key generator (10), an ephemeral key generation and/or credentials signing upon activation by the user;

transmitting, by the personal cryptographic key generator (10), the generated ephemeral keys and/or signed credentials to the cryptographic processor (30);

forwarding, by the cryptographic processor (30), a verification key of the personal

cryptographic key generator (10) to the verification processor (40); and
binding, by the verification processor (40), the verification key with the user's profiles
including pseudo/Official Digital Identities.

- 5 3. The computer implementable protocol according to claim 1 or claim 2, wherein the
protocol, during the operation process for user to login into a targeted service
provider's system, comprises the steps of:
providing, by the user interface (20), functional options for the user to select and
execute upon successful establishment of the momentary trusted zone established and
10 user authentication completed with non-interactive Zero Knowledge Proof
cryptographic primitive;
instructing, by the cryptographic processor (30), the user interface (20) to request for
activating the personal cryptographic key generator (10) upon receiving one or more
instruction messages of the function options which required signatures from the user
15 interface (20);
instructing, by the user interface (20), the user to activate the personal cryptographic
key generator (10);
performing, by the personal cryptographic key generator (10), an ephemeral key
generation and/or credentials signing upon activation by the user;
20 transmitting, by the personal cryptographic key generator (10), the newly generated
ephemeral keys and/or signed credentials to the cryptographic processor (30);
performing, by the cryptographic processor (30), signature signing on the instruction
messages; and
transmitting, by the cryptographic processor (30), the signed instruction messages, the
25 signed credential, and a newly generated verification key to the verification processor
(40) that will complete the user authentication using the non-interactive Zero
Knowledge Proof cryptographic primitive to complete the login operation into the
targeted service provider's system.

4. The computer implementable protocol according to any one of claims 1 to 3,
wherein the personal cryptographic key generator (10) comprises a physical isolation
arrangement for protecting it physically against unauthorised access and a
counterparty cryptography processor to establish the data transfer link in a secure
5 fashion via one or more cryptographic protocols.

5. The computer implementable protocol according to any one of claims 1 to 4,
wherein the personal cryptographic key generator (10) comprises a notifier to provide
a notification of a current operation status.
10

6. The computer implementable protocol according to any one of claims 1 to 5,
wherein the one or more input modules (12) are in the form of one or more biometric
sensors for capturing biometric traits of a user and a processor for verifying an
identity of the user using an in-device hardware secure memory stored template
15 and/or template-free Artificial Intelligent driven biometric authentication method,
whereby the ephemeral keys and credentials are respectively generated and signed
upon successful verification of the user's biometric.

7. The computer implementable protocol according to any one of claims 1 to 6,
20 wherein the one or more input modules (12) are in the form of one or more
mechanical or electric actuators for receiving inputs from the user.

8. The computer implementable protocol according to any one of claims 1 to 7,
wherein the vibration module (13) is a piezoelectric vibrator or electro-magnetic
25 actuator.

9. The computer implementable protocol according to claim 8, wherein the
piezoelectric vibrator or electro-magnetic actuator is stacked with the one or more
input modules.

10. The computer implementable protocol according to claim 8, wherein the piezoelectric vibrator or electro-magnetic actuator is arranged to partially or entirely surround the one or more input modules.

5

11. The computer implementable protocol according to any one of claims 1 to 10, wherein the generated ephemeral keys and/or signed credentials are of a predetermined structure and size for them to be transmitted in a consistent and secure manner.

10

12. The computer implementable protocol according to any one of claims 1 to 11, wherein the credential is signed using one or more hashing algorithms with Digital Signature Algorithms executed by secured hardware accelerated execution of user's identity binded personal cryptographic key generator (10).

15

13. The computer implementable protocol according to any one of claims 2 to 12, wherein the personal cryptographic key generator (10) comprises a QR code that contains the unique identity of the personal cryptographic key generator (10), and the unique identity is retrievable through scanning the QR code.

20

14. The computer implementable protocol according to any one of claims 3 to 13, wherein the cryptographic processor (30) is configured to perform a cascading signature operation that signs a batch of instruction messages.

25

15. A personal cryptographic key generator (10) in the form of a wirelessly charged battery powered card comprising:

a card body (11);

one or more input modules (12) to which a user can interact therewith for activating the personal cryptographic key generator (10);

a vibration module (13) configured to vibrate the one or more input modules or at least one section of the card body;

a transmission module (14) for establishing a data transfer link to connect with a device which the user interface (20) is operated thereon via a communication
5 protocol;

a battery (15) for supply electricity to components of the personal cryptographic key generator (10); and

a processing unit (16) connected to the one or more input modules (12), the vibration module (13), the transmission module (14), and the battery (15);

10 wherein the processing unit (16) is configured to:

(a) generate ephemeral keys and sign credentials upon the user activates the personal cryptographic key generator (10) via the one or more input modules (12);

(b) instruct the vibration module (13) to perform a vibration pattern selected
15 from a plurality of pre-stored vibration patterns based on predetermined conditions when the user interacts with the one or more input modules (12);

(c) operate the cryptographic key generator (10) entirely in an offline mode with the exception of a single instance where the personal cryptographic key generator (10) is switched to an online mode in which the data transfer link is
20 established to transmit the generated ephemeral keys and/or the signed credentials, and after which it switches back to the offline mode; and

(d) operate in an unbalance communication mode where the personal cryptographic key generator (10) exclusively initiates and/or disconnects the data transfer link.

25

16. The personal cryptographic key generator (10) according to claim 15, the one or more input modules (12) are in the form of one or more biometric sensors for capturing biometric traits of a user and the processor unit (16) for verifying an identity of the user using an in-device hardware secure memory stored template and/or

template-free Artificial Intelligent driven biometric authentication method, whereby the ephemeral keys and credentials are respectively generated and signed upon successful verification of the user.

5 17. The personal cryptographic key generator (10) according to claim 15 or claim 16, wherein the one or more input modules (12) are in the form of one or more mechanical or electric actuators for receiving inputs from the user.

18. The personal cryptographic key generator (10) according to any one of claims 15
10 to 17, wherein the vibration module (13) is a piezoelectric vibrator or an electro-magnetic actuator stacked with the one or more input modules.

19. The personal cryptographic key generator (10) according to claim 18, wherein the piezoelectric vibrator or electro-magnetic actuator is arranged to partially or entirely
15 surround the one or more input modules.

20. The personal cryptographic key generator (10) according to claim 15, wherein the battery is wirelessly rechargeable by wireless charging modules (27, 28) having a coil or antenna (28) for capturing the electromagnetic field generated by an external
20 transmitter and a rectifier and control circuitry (27) for converting an initial current induced in the coil or antenna (28) into a current voltage suitable for charging the battery (15).