System and methods for generating trusted and authenticatable time stamps for electronic documents
CA 2398415 A1

ABSTRACT
A trusted time infrastructure system provides time stamps for electronic documents from a local source. The system comprises a trusted master clock (204), a trusted local clock (206), and a network operations center (210). The trusted master clock and network operations center are located within secure environments controlled by a trusted third party. The trusted local clock may be located in an insecure environment. The trusted master clock is certified to be synchronized with an accepted time standard, such as a national time server (202). The trusted local clock, which issues time stamps, is certified to be synchronized with the trusted master clock. Time stamps and certifications are signed by the issuing device using public key cryptography to enable subsequent authentication. The network operations center logs clock certifications and responds to requests for authentication of time stamps.

DESCRIPTION (OCR text may contain errors)
SYSTEM AND METHODS FOR GENERATING TRUSTED AND AUTHENTICATABLE TIME STAMPS FOR ELECTRONIC DOCUMENTS
Background of the Invention Field of the Invention This invention relates generally to methods and systems for providing and verifying a trusted source of certified time, and, more particularly, the invention relates to digitally time stamping electronic documents wherein the time stamp can be validated and verified as synchronized with an accepted standard.
Description of the Related Art Electronic Commerce (e-commerce) is a rapidly expanding aspect of the economic world and demands the use of Electronic Commerce transactions. Such transactions, however, have outgrown the policing and controls that regulate traditional Paper Commerce. For example, a paper document can be typed, signed in ink, and mailed through the postal office. The post office can then affix a time stamp and receipt at the destination. There are long standing legal and accounting policies that authenticate this type of transaction. When an electronic document is sent between two computers, however, it does not leave behind the same degree of tangible evidence. Even if the electronic document is stored in a computer's memory, the contents, signature, and time stamp can be manipulated by anyone with access to the computer.
Accounting and legal regulatory bodies are currently developing and mandating Electronic Commerce certification processes to provide reliable authentication for electronic transactions much like those available for paper transactions. Many of the certification processes depend on the creation of a digital signature using public key cryptography that authenticates the "Who," "What," and "When" of a document.
Public key cryptography was developed in the 1970s to solve problems involved with symmetric key cryptography.
In public key cryptography systems, two corresponding keys are generated. One key, called a private key, is held privately by the keyholder. A second key, called a public key, is published openly for anyone that wants to secretly communicate with the keyholder. A second key, called a private key, is held privately by the keyholder. A second key, called a private key, is held privately by the keyholder. A second key, called a private key, is held privately by the keyholder.

CLAIMS (28)
1. A system for providing a source of time certified to be synchronized with an accepted standard, the system comprising:
a trusted master clock certified to be synchronized to the accepted standard, the trusted master clock, maintained within a secure environment under control of a trusted third party;
a trusted local clock certified by the trusted master clock to be synchronized with the trusted master clock, wherein the trusted local clock is a tamper-resistant device configured to be located in an insecure environment, and wherein the trusted local clock is configured to provide trusted temporal tokens and to increment an internal log of the number of trusted temporal tokens provided; and
a network operations center configured to provide verification information for verifying the certification of clocks within the system, the network operations center maintained within a secure environment under control of a trusted third party.

2. The system of claim 1, wherein the verification information comprises a time calibration certificate of a certified clock.
3. The system of claim 1, wherein the verification information comprises a public key of a clock.
4. The system of claim 1, wherein the verification information comprises an indication of the validity of a submitted trusted temporal token.
5. The system of claim 1, wherein the network operations center is further configured to receive certification information from the trusted master clock.
6. The system of claim 5, wherein the certification information comprises a time calibration certificate of a certified clock.
7. The system of claim 1, wherein the network operations center is
wish the keyholder or verify the authenticity of messages sent by the keyholder.
Because the sender and the receiver use different keys, public key cryptography
is also known as asymmetric key cryptography.
To send a secret message with public key cryptography, an entity "A" encrypts a
message using the public key of an entity "B." "A" then transmits the encrypted
message to "B." "B" decrypts the encrypted message with "B"s corresponding private key. Since the
message encrypted with "B"s public key can only be decrypted with the corresponding private key, held only by "B," the privacy of the communication is
ensured.
To authenticate the content and origin of a message, "A" uses a one-way hash
function to create a message digest.
A message digest is a fixed length data element that uniquely represents the
source message. Since the hash function is one-way, nothing about the content of
the source message can be inferred from the message digest. For example, two
message digests from two messages that differ by only one character would appear to be a completely random reordering of characters.
"A" then signs the message by encrypting the digest using "A"s private key.
The signature is typically appended to the message itself. "A" then transmits the
signed message to "B." In order to authenticate the received message, "B" uses
the same one-way hash function used by "A" to create a message digest from the
received message. "B" then decrypts the encrypted digest using "A"s public key.
If the decrypted digest matches the digest created from the received message,
then the received message must be the identical message from which the
decrypted digest was originally derived. Furthermore, that the decrypted digest
decrypted using "A"s public key ensures that the decrypted digest was
originally encrypted with "A"s private key. The successful matching of digests,
therefore, ensures that the message received by "B" is the identical message
signed by "A."
Encrypting a message itself establishes secrecy. Signing a message provides for
message authentication and establishes the 'who' and 'what' of a message.
Encryption and signatures can also be combined by encrypting a message before
creating a message digest and signature. By combining encryption and
signatures, secret, authenticatable communications can be accomplished.
A very significant attribute of public key cryptography is that there is no need to
share a secret key or to transmit a secret key from the keyholder to a proposed
communication partner. It is, however, necessary to establish credibility for who
owns public and private keys. For instance,"C" could claim to be "A" and send a
message to "B." To prevent being fooled, "B" needs to be sure that"A"s public key, is
in fact paired with the private key owned by a realA." A Certification Authori-ty
(CA) solves this problem. (Note: The use of the word'certification' in certification
authority relates to the association of public keys with particular owners and is
distinct from the concept of a Time Calibration Certificate (TCCert), as used
herein, which relates to the certification of a clock as synchronized with an
accepted standard.) CAs provide digital certificates which contain public keys and are
used to transmit the public keys in a secure, authenticated manner to
participants in e-commerce transactions.
in addition to the cryptographic techniques and digital certificates provided by
CAs, security and authentication of transactions is also supported by an extensive
body of protocol standards. It is necessary for "A" to format messages, signatures,
message digests, etc., with protocols that can be recognized by "B."
Cryptography, digital certificates, protocols, and standards together make up what
is termed the Public Key Infrastructure (PKI). With PKI, one can easily guarantee the 'who'
and 'what' of a transaction.
"When" is a measure of the time at which an event occurred and is a concept
easily taken for granted. A worldwide system of time standardization is in
operation. Each country that is signatory to the Treaty of the Meter maintains a
National Timing Laboratory (NTL), which houses the local country's standard time
clocks.
These clocks are kept synchronized to the world standard of time maintained in
Paris, France. The world standard for commercial time is Coordinated Universal
Time (UTC) and is maintained by the US National Institute of Standards and
Technology (NIST). UTC is derived from the international atomic clock (IATC) at
the National Institute of Standards and Technology in Boulder, Colorado.

8. A system for time stamping digital documents, wherein the time from which the
time stamp is derived is certified to be synchronized to an accepted standard, the
system comprising:

a trusted master clock certified to be synchronized to the accepted standard, the
trusted master clock maintained within a secure environment under control of a
trusted third party;

a trusted local clock certified by the trusted master clock to be synchronized with
the trusted master clock, the trusted local clock configured to provide time stamps
and to increment an internal log of the number of time stamps provided, the
trusted local clock being a tamper-resistant device configured to be located in an
insecure environment; and a network operations center configured to provide time
stamp verification information, the network operations center maintained within a
secure environment under control of a trusted third party.

9. The system of claim 8, wherein the verification information comprises
a time calibration certificate of a certified clock.

10. The system of claim 8, wherein the verification information
comprises a public key of a clock.

11. The system of claim 8, wherein the verification information
comprises an indication of the validity of a submitted time stamp.

12. The system of claim 8, wherein the network operations center is
further configured to log time calibration certifications.

13. A method of providing trusted temporal tokens, the method comprising:
maintaining a trusted master clock within a secure environment;
certifying a trusted local clock to be certified as synchronized with a trusted
time server;

causing the trusted master clock to be certified as synchronized with a trusted
local clock;

certifying a trusted local clock to be synchronized with the trusted master clock,
the trusted local clock being configured to provide trusted temporal tokens, the
trusted local clock being a tamper-resistant device configured to be located in an
insecure environment; and providing trusted temporal token verification
information in response to verification requests.

14. The method of claim 13, further comprising providing trusted
temporal tokens through the trusted local clock in response to time
stamping requests.

15. The method of claim 13, wherein the verification information
comprises a time calibration certificate of a certified clock.

16. The method of claim 13, wherein the verification information
comprises a public key of a clock.

17. The method of claim 13, wherein the verification information
comprises an indication of the validity of a trusted temporal token.

18. The method of claim 13, wherein the verification information
is provided by a network operations center, the network operation center being
maintained within a secure environment.

19. The method of claim 13, further comprising logging the certifications
of the clocks.

20. The method of claim 13, further comprising logging the number of
trusted temporal tokens issued by the trusted local clock.

21. The method of claim 13, further comprising billing a client based on
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Time (UTC). In the United States, Congress has mandated that official United States time follow the clock maintained by the National Institute of Standards and Technology (NIST), located in Boulder, Colorado. This standard is referred to as UTC-NIST. Any time stamp for a transaction that must survive technical, auditing, or legal scrutiny must be made by a clock that is synchronized to UTC-NIST, and the synchronization process must be "traceable." Throughout this document, reference is made to UTC-NIST but the invention described is applicable to operation in any country and with standard time clocks maintained by any country's respective national timing laboratory. The use of "traceable" clocks in paper commerce has been sufficient to provide the "when" of ordinary paper transactions. While there have been numerous cases of falsification of dates on paper documents, the risk to commerce has been relatively small. In the case of e-commerce, however, falsification of dates creates a much greater risk because it is possible to invade computer-directed processes and effect fraud on a very large scale. Such computer crimes frequently involve falsification of electronic time stamps; and for this very reason, protection of the electronic clocks that generate those time stamps from tampering is a high priority in Electronic Commerce.

Current network procedures provide for the synchronization of all workstation clocks in a network. NIST and other agencies provide network time servers that have clocks traceable to UTC-NIST. Client workstations can synchronize their time with the network time servers through a common protocol. The Network Time Protocol (NTP) is commonly used in TCP/IP networks such as the Internet, but other protocols are also used. Unfortunately, once a local workstation clock is synchronized to the network time server, its time may be subject to manipulation regardless of the reliability of the source network time server. Thus far, little work has been done to ensure that the source of the time used to generate time stamps can be trusted. Today, the majority of applications utilizing time stamps simply use the system clock from their host system. Procedures for setting or offsetting a system clock are commonly known. Thus, there is no inherent trust in a system clock in a conventional system.

Attempts to overcome this problem include time stamp sequencing wherein the time stamp incorporates information regarding the order in which documents are time stamped in relation to other time-stamped documents. (See, for example, U.S. Patent 5,136,647 to Haber et al.) Other attempts to overcome the problem incorporate the use of other time sources such as NTP or Global Positioning System (GPS). While these attempts are significant improvements over using the system clocks, the improvements still fall short of fitting into the trust models required for electronic business today. Still other systems employ the use of certified time that is maintained by a trusted third party's system located outside the local network. The trusted third party system remains synchronized with UTC-NIST through a common protocol. The local network application server then establishes communication with the third party's system whereby a data object (document or message digest) is sent to the third party system where it is "time stamped" and affixed to the data object, either in clear text or in cryptographically embedded text. Such a system may be impractical, however, considering the need for external communication for each instance of time stamping, especially when many time stamps are required by the local network.

Another system introduces a local clock into the local network, thus avoiding the problems associated with obtaining time stamps from an outside source. The local clock must be periodically synchronized with a UTC-NIST traceable clock. In order to avoid frequent certification and calibration between the local clock and the UTC-NIST traceable clocks, the kHz-1 dodo is advantageous a cesium atomic dodos. Cesium atomic clocks are commercially available and their frequency, and hence time, is derived from an atomic phenomena caused by the energy difference of certain cesium atom electron orbits. Thus, as long as the cesium atomic clock is operating, it will be accurate enough to satisfy most practical applications. Such clocks only lose one second in 30,000 years of normal operation. For this reason, cesium atomic clocks are termed "primary reference sources." Unfortunately, when used locally, there is still the possibility that the time value in the dodo could, through system malfunction or intentional manipulation, be altered to an incorrect value that would not be apparent to a user.

Trusted time, in the context of the present invention, is time that is certified to be traceable to the legal time source for the application in which it is being used. The legal time source for commercial applications operating in the United States, as legislatively mandated by Congress, is the National Institute of Standards and Technology (NIST). The infrastructure for providing trusted time must provide a strong trust model, including a certification log for auditing and to prevent repudiation at a later date.

The need for trusted time has become recognized over the last two years as marked by the launch of standardization activities in the The Internet Engineering Task Force (IETF), in addition, most Certification Authority (CA) product and service vendors have announced development activities and new products in this area. The present disclosure describes a Trusted Time Infrastructure (TTI) that meets the requirements for providing trusted time. The present disclosure also shows how the

21. A method of generating revenue comprising providing trusted temporal tokens through a trusted local clock in exchange for fees.

22. The method of claim 21, wherein the recipient is billed based upon the number of time stamps provided to the recipient.

23. A method through which a business entity provides electronic time stamps in exchange for fees, the method comprising:

- providing time stamps to a recipient through a trusted local clock, wherein the trusted local clock is located in an environment not controlled by the business entity;
- and billing the recipient for the service of providing time stamps.

24. The method of claim 23, wherein the recipient is billed based upon the number of time stamps provided to the recipient.

25. The method of claim 23, wherein the trusted local clock is certified by a trusted master clock to be synchronized with the trusted master clock.

26. The method of claim 23, wherein the recipient is billed for a certification of the calibration of the trusted local clock.

27. A method of generating revenue comprising providing trusted temporal tokens through a trusted local clock in exchange for fees.

28. A method of generating revenue comprising certifying a trusted local clock to be traceably synchronized to an accepted standard in exchange for a fee.
One embodiment of the invention is a method through which a business entity provides electronic time stamps in exchange for the number of trusted temporal tokens issued by the trusted local clocks. The method can also include billing a party. The verification information can include a time calibration certificate of a certified clock. The network operations center can be further configured to receive certification information from the trusted master clock. The certification information can include a time calibration certificate of a certified clock. The network operations center can also be configured to log time calibration certificates.

One embodiment of the invention is a system for providing a source of time certified to be synchronized with an accepted standard. The system includes a trusted master clock certified to be synchronized to the accepted standard, wherein the trusted master clock is maintained within a secure environment under control of a trusted third party. The system also includes a trusted local clock certified by the trusted master clock to be synchronized with the trusted master clock, wherein the trusted local clocks is a tamper-resistant device configured to be located in an insecure environment. The system can also include a network operations center configured to provide verification information for verifying the certification of clocks within the system. The network operations center can be maintained within a secure environment under control of a trusted third party. The verification information can include a time calibration certificate of a certified clock. The verification information can include a public key of a clock. The trusted local clock can be configured to provide trusted temporal tokens. The verification information can include an indication of the validity of a submitted trusted temporal token. The network operations center can be further configured to receive certification information from the trusted master clock. The certification information can include a time calibration certificate of a certified clock. The network operations center can also be configured to log time calibration certificates.

The trusted master clock is certified to be synchronized with an accepted time standard, such as a national time server. The trusted local clock, which issues time stamps, is certified to be synchronized with the Dusted master clocks. Time stamps and certifications are signed by the issuing device using public key cryptography to enable subsequent authentication. The network operations center logs dodo certifications and responds to requests for authentication of time stamps. The delivery of trusted time by the trusted local clocks ensured by: (f) the physical security of the devices in the system; (2) the link of certifications through which time can be traced to an accepted standard; and (4) the specified accuracy of clocks within the system.

In an alternative embodiment, each issued time calibration certificate incorporates the time calibration certificate of the issuing clock. The time calibration certificate of the trusted local clock is then incorporated into the issued trusted temporal tokens. Accordingly, the chain of certifications from which trusted time is derived from an accepted source is incorporated into each trusted temporal token.

In another embodiment, the system provides a local source of trusted time through a trusted local dodo. In still another embodiment, methods of billing clients are based upon the number of trusted temporal tokens issued or, alternatively, based upon the number of clock certifications performed. Billing features of the system support the billing methods. These and other aspects of the present invention will be further described in the detailed description that follows.

One embodiment of the invention is a system for providing trusted time from which binding electronic transactions can take place today. TTI fits in with the trust models and cryptographic standards that have been developed to ensure that secure and legally binding electronic transactions can take place today.
for fees. The method includes providing time stamps to a recipient through a trusted local clock, wherein the trusted local clock is located in an environment not controlled by the business entity. The method also includes billing the recipient for the service of providing time stamps. The recipient can be billed based upon the number of time stamps provided to the recipient. The trusted local clock can be certified by a trusted master clock to be synchronized with the trusted master clocks. The recipient can be billed for a certification of the calibration of the trusted local clock.

One embodiment of the invention is a method of generating revenue. The method includes proving trusted temporal tokens through a trusted local clock in exchange for fees.

One embodiment of the invention is a method of generating revenue. The method includes certifying a trusted local clock to be traceably synchronized to an accepted standard in exchange for a fee.

Brief Description of the Drawings The preferred embodiments of the present invention are described below in connection with the drawings in which like reference numbers represent corresponding components throughout, and in which:

Figure 1 illustrates the four principal levels of the global timing hierarchy;

Figure 2 illustrates a schematic of the key components of a preferred embodiment of the TTI and the key transactions between these components;

Figure 3 illustrates a functional block diagram of the Network Operations Center;

Figure 4 illustrates one embodiment of a TTI system including a network of clocks and applications;

Figure 5 illustrates an overview of the process by which a preferred embodiment of the TTI system generates trusted temporal tokens;

Figure 6 illustrates a preferred embodiment of the process by which an upper dodo certifies the time of a lower dodo;

Figure 7 illustrates a preferred embodiment of the process by which trusted temporal tokens are generated by a Trusted Local Clock and Figure 8 illustrates a process by which an application can verify the authenticity of a trusted temporal token.

Detailed Description of the Preferred Embodiment In the following description, reference is made to the accompanying drawings, which form a part hereof, and which show, by way of illustration, specific embodiments in which the invention may be practiced. It is to be understood that other embodiments may be utilized and structural changes may be made without departing from the scope of the present invention.

Where possible, the same reference numbers will be used throughout the drawings to refer to the same or like components. Numerous specific details are set forth in order to provide a thorough understanding of the present invention. However, it will be understood by one skilled in the art that the present invention may be practiced without the specific details or with certain alternative equivalent devices and methods to those described herein. In other instances, well-known methods, procedures, components, and devices have not been described in detail so as not to unnecessarily obscure aspects of the present invention.

1. Global Timing Hierarchy As illustrated in Figure 1, the global timing hierarchy has four principal levels:


Application Layer The Trusted Time Infrastructure (TTI) provides a system for commercial or private timing distribution services to deliver to the application layer a "trusted temporal token" or "trusted time stamp" that cryptographically binds the current time of day derived from the NTA to a unique data request submitted by an application.

Such a request may be made in response to events, transactions, or document submittals, public key digital signatures are preferably used as the binding mechanism to ensure the identity of the time distribution service and to protect the temporal token from undetected manipulation.

The time delivered by the TTI is preferably Universal Coordinated Time (UTC). The means by which the NTAs synchronize their UTC clocks (e.g., UTC(NIST)) with the International Bureau of Weights and Measures (BIPM) in France is outside of the scope of this disclosure. However, the UTC delivered by most of the major NTAs can be expected to be within nanoseconds of UTC (BIPM), while any of the other NTAs are still within microseconds of UTC (BIPM). Thus, for trusted time applications, where time is typically certified to be accurate to within 100 milliseconds at the application layer, the choice of which NTA to use is a legal issue for a particular country and not one of accuracy.

2. Trusted Time Infrastructure (TTI) Figure 2 illustrates a schematic of the key components of a preferred embodiment of the TTI and also illustrates the key transactions between these components. The embodiment of Figure 2 comprises an NTA Trusted Time Server (NTTS) 202, a Trusted Master Clock or Trusted Third Party Clock (TMC) 204, a Network Operations Center (NOC) 210, a Trusted Local Clock (TLC) 206, and an application 208. Although only one instance of each component is depicted in figure 2 for instructive purposes, numerous instances of each element may be present in an actual TTI system.

2.1 Secure Communication Through Public Key Infrastructure (PKI) The various elements in the TTI system communicate securely using PKI.

Although PKI is often used to encrypt confidential communications, PKI can also be used to verify the origin of a communication through digital signatures. In the TTI system, the privacy of the communication between elements is generally not an issue. Instead, it is the authenticity of the communication that is generally of concern.

PKI authentication supports two aspects of the TTI system. First, PKI authentication supports authentication of communications between elements in the TTI system in order to maintain the integrity of the system as a whole. For example, if a Trusted Master Clocks (TMC) 204 communicates with a Trusted Local Clock (TLC) 206 in order certify its time calibration, the TMC 204 must know for sure the identity of the TLC 206 that it is certifying. In another example, if a TMC 204 notifies the Network Operations Center (NOC) 210 of a time calibration...
certification of a TLC 206, the NOC 210 must be able to authenticate the identity of the certifying TMC 204. In an additional example, if a TMC 204 is capable of adjusting the time of a TLC 206, the TLC 206 must be able to verify that it is indeed a valid TMC 204 that is adjusting its time. In accordance with this first aspect, trusted temporal tokens preferably include the signed time calibration certification of the certifying cloud. The NOC 210, through its PKI authentication capabilities, provides a system through which trusted time can be traced to the NTA Trusted Time Server (NTTS) 202 from any TLC 206 through authenticated time calibration certifications. In other words, the source of time from which a trusted temporal token has been derived can be traced back through signed time certifications to the NTTS 202.

A second aspect in which PKI authentication supports the TTI system is in authentication of temporal tokens themselves. The trusted temporal token includes a signed concatenation of a digest of the message to be time stamped as well as the time calibration certification of the issuing TLC 206. This signed concatenation allows the authenticity of the temporal token itself to be verified as being unaltered and issued by a particular TLC 206.

2.2 Key System Elements

2.2.1 Trusted Time Server

The NTA Trusted Time Server (NTTS) 202 is the highest level node in the TTI and is preferably located in a secure environment under government control. The NTTS 202 is the source of legal time from which the TTI derives its trusted time. The secure environment should be accessible only to trusted agents of the government timing authority (e.g., NIST), in order to ensure the integrity of the NTTS 202. The NTA is responsible for monitoring the accuracy of the NTTS-produced time and the operation of the NTTS 202 itself.

The NTTS 202 is responsible for measuring the local offsets of the TMC 204 units. The NTTS 202 preferably performs this measurement over the Public Switched Telephone Network (PSTN). To measure the local offsets of the TMCs, the NTTS 202 preferably supports a variant of Network Time Protocol (NTP) called Secure NTP (SNTP). NTP has been in use as a standard Internet Protocol since the early 1980s. SNTP is currently before the IETF as a draft protocol. It differs from NTP primarily in the establishment of a more robust authentication scheme based on more modern PKI techniques. For redundancy, two NTTS units are preferably located at the NTA, preferably at geographically separate locations.

2.2.2 Trusted Master Clods

The Trusted Master Clods (TMC) 204 is an intermediary cloud that serves to pass a trusted source of time from the NTA Trusted Time Server (NTTS) 202 to the Trusted Local Clock (TLC) 206 where the trusted time is actually used. The TMC 204 is preferably a stand-alone server located in a secure environment under the control of a trusted third party. This trusted third party can be the entity or organization implementing the whole TTI system or part of the TTI system. Lain, the secure environment is preferably accessible only to trusted agents of the trusted third party to prevent tampering with the TMC 204.

Only one TMC is illustrated in Figure 2 for teaching purposes. Typically, however, the TTI network will contain a minimum of two TMCs. In some configurations, two or more TMCs may be linked in series between the NTTS 202 and the TLC 206. These and other configurations will be shown below.

The TMC 204 preferably comprises a Rubidium oscillator; a GPS receiver for monitoring the oscillator; cryptographic hardware; and a timing engine that generates trusted time. Each TMC 204 has a set of TLCs that it is responsible for time._7.

certifying. These sets of TLCs will be assigned by the Network Operations Center (NOC) 210. Preferably, the NOC 210 will ensure that at least two TMCs will be assigned to each TLC. This structure ensures sufficient redundancy so that the failure of a single TMC will not affect the operation and trust of the TLCs. It should be understood that a non-redundant configuration can be advantageously used when redundancy is not a concern.

The TMC 204 preferably uses the NIST operating system configured for enhanced security. The TMC housing is designed to meet NIST Federal Information Processing Standard (FIPS) 140-1 Level 3 physical protection and tamper detection requirements (FIPS 140-1 is titled "Security Requirements for Cryptographic Modules"). Cryptographic calculations, including key generation, are performed by dedicated hardware. In the preferred embodiment, the private signing key of the TMC 204 is never exported from the cryptographic card.

The cryptographic device also contains a high-quality random number generator that can be used to generate new PKI key pairs. Sensitive cryptographic information is preferably contained in battery-backed memory, which will be erased in the event of a tamper alarm. The TMC 204 is preferably designed to receive a NIST validation rating of FIPS 140-1 Level 1 overall and Level 3 for physical security.

Audit trails are created for all TMC events, including all operator actions (logs include operator IDs), alarms, time certifications, and all remote NOC communications. These logs are digitally signed to prevent (by detection) subsequent forgery or alteration. The TMC 204 will typically include a GPS receiver that can be used to initialize the TMC 204 and to monitor the health of the TMC 204. If any abnormalities are detected in the TMC time source, the TMC 204 goes off line, attempts to isolate the problem, and shuts down.

The TMC 204 uses Secure NTP (SNTP) and User Datagram Protocol (UDP) to access each of its assigned TLCs periodically to measure its time offset. If the time of TLC 206 is within a certain offset (typically 100 ms) from the NTTS 202, the TMC 204 certifies the TLC 206 to be within that offset. The TMC 204 may also send small time corrections to the TLC 206 that can be used to make adjustments to the TLC 206 clock to keep it within specification. If a TMC 204 finds that a TLC 206 has a valid,
2.2.5 Application The application 208 is any process or device that requests trusted temporal tokens from the TLC 206. The application 208 can run on the same server that hosts the TLC or the application 208 can run on any other machine in communication with the host server. The application 208 can request verification of a time stamp through the NOC 210.

Alternatively, a time stamp obtained by an application 208 can be passed to another application. The other application can run on the same server that hosts the TLC or the application can run on any other machine in communication with the host server. The application can communicate with the NOC 210.

The TLC 206 preferably never be exported from the PCMCIA cryptography engine. The cryptography device preferably also contains a high quality pseudorandom number generator. Key generation is performed on the PCMCIA device. The private key for the TLC 206 will preferably never be exported from the PCMCIA cryptography engine.

Sensitive cryptographic information is contained in battery-backed memory that is preferably erased in the event of a tamper alarm. The TLC 206 preferably has a NIST validation rating of FIPS 140-1 Level 3 for physical security.

Audit trails are preferably created for all TLC events, including all operator actions (logs include operator IDs), alarms, time certifications performed, temporal tokens issued, and all remote NOC 210 communications. These logs are digitally signed to prevent (by detection) subsequent forgery or alteration.

Like the TMC 204, the TLC 206 can include a GPS receiver to initialize the TLC 206 and to monitor the health of the TLC 206. If any abnormalities are detected in the TLC time source, the TLC 206 goes off line, attempts to isolate the problem, and shuts down.

2.2.4 Trusted Local Clocks The Trusted Local Clock (TLC) 206 provides trusted time, preferably in the form of a trusted temporal token, to the application 208 on request. The TLC 206 is hosted in a customer-owned server and is preferably a PCIv2.1 compliant card that is tamper-resistant and is assumed to be operating in an insecure host in an insecure environment.

The TLC 206 comprises an oscillator and a timing engine, which generates trusted time. A Time Calibration Certificate (TCCert) typically has a period during which it is valid. The range of accuracy specified by the TCCert during the valid period accounts for the accuracy of the TLC's oscillator and timing engine. The TCCert therefore, serves as assurance of the accuracy, during the valid period, of the certified clock.

The TLC 206 preferably uses a real-time operating system to control the on-card functions. The TLC 206 preferably has its own Ethernet TCP/IP connection for communications with the TMC 204 and NOC 210.

Cryptographic calculations in the TLC 206 are preferably performed using a dedicated hardware PCMCIA (Personal Computer Memory Card International Association) cryptography engine. This cryptographic device preferably also contains a high quality pseudorandom number generator. Key generation is performed on the PCMCIA device. The private key for the TLC 206 will preferably never be exported from the PCMCIA cryptography engine.

Sensitive cryptographic information is contained in battery-backed memory that is preferably erased in the event of a tamper alarm. The TLC 206 preferably has a NIST validation rating of FIPS 140-1 Level 1 overall and Level 3 for physical security.

Audit trails are preferably created for all TLC events, including all operator actions (logs include operator IDs), alarms, time certifications performed, temporal tokens issued, and all remote NOC 210 communications. These logs are digitally signed to prevent (by detection) subsequent forgery or alteration.

Like the TMC 204, the TLC 206 can include a GPS receiver to initialize the TLC 206 and to monitor the health of the TLC 206. If any abnormalities are detected in the TLC time source, the TLC 206 goes off line, attempts to isolate the problem, and shuts down.

The NOC 210 comprises three additional functional components that implement the PKI authentication capability of the TTI system. The Registration Authority (RA) 312 associates each device in the TTI system with a name. In this manner, TTI devices can be identified, monitored, and controlled. The Certification Authority (CA) 314 associates a public key with each device using the name of the device provided by the RA 312. The Online Certificate Status Protocol (OCSP) responder 316 responds to requests for digital certificates for devices in the TTI system. The OCSP responder 316 serves as a trusted source of digital certificates. Digital certificates provide a data structure associating a public key with a signing device and allow verification and authentication of the signed communications of TTI devices.

Since the NOC 210 knows an elements comprising the TTI, the NOC 210 acts as an RA 312 to the CA 314 for the issuance of digital certificates to the TTI elements.

The TTI preferably uses ITU-T X.509v3 digital certificates. Each element within the TTI preferably has a distinguished name so that it may be uniquely identified. The name structure is preferably aligned with the International Telecommunications Union - Telecommunication Standardization Sector (ITU-T) X.501X.520 standards for distinguished names. The use of an RA, a CA, and an OCSP responder is known in the art and information regarding this topic is available from entities such as the IETF (Internet Engineering Task Force).

The NOC 210 preferably also comprises a billing system 318 that interacts with the element manager 306 and the database 308 in order to assemble client billing information. A number of different billing schemes will be discussed in the section on billing below.

2.2.3 Network Operations Center The Network Operations Center (NOC) 210 serves as the central control facility for the TTI system. The NOC 210 is preferably located in a secure environment under the control of a trusted third party.

Figure 3 illustrates a functional block diagram of the NOC 210. The NOC 210 communicates with the various elements of the TTI through a communications network 302. The communications network 302 may comprise the Public Switched Telephone Network (PSTN), the Internet, and/or other computer networks. A firewall 304 protects the internal systems of the NOC 210 from external attack through the communications network 302. The NOC 210 comprises an element manager 306, which is a configuration and maintenance system that has the ability to remotely configure and monitor the NTTS 202, TMCs 204, and TCLs 206 using a secure management protocol. In addition, the NOC 210 comprises a central database 308 that is used to store all TMC and TLC time certification logs.

The NOC 210 also comprises a web server 310 that handles temporal token verification requests sent via the World Wide Web. The web server 310 interfaces with the element manager 306 to initiate a verification action and to return the response to the requestor. The web server 310 preferably uses Secure Sockets Layer (SSL) with server authentication in order to encrypt and authenticate the server data exchanged between the client and the server. The NOC 210 further comprises a billing system 312 for trusted time service subscribers. The billing system 312 logs data regarding the number of tokens issued by a TLC 206.

The NOC 210 comprising is a trusted system that hosts the TLC 206. The NOC 210 comprises a web server 310 that receives requests for digital certificates from the TTI elements. The web server 310 preferably creates a digital certificate for each element in the TTI, and issues the digital certificate to the element manager 306. The element manager 306 distributes the digital certificate to the element within the TTI.

The NOC 210 comprises a billing system 318 that interacts with the element manager 306 and the database 308 in order to assemble client billing information. A number of different billing schemes will be discussed in the section on billing below.
then perform the verification of the time stamp through the NOC 210.

Client applications 208 access the TLC 206 using a Trusted Time Application Program Interface (TTAPI). The TTAPI will communicate with its associated TLC 206 using the Transport Layer Security/Secure Sockets Layer (TLS/SSL) protocol.

Server applications co-located wish a TLC 206 access the TLC 206 using a Trusted Local Clock Application Interface.

2.3 TTI System Figure 4 illustrates some embodiment of a TTI system 400 including a network of clocks and applications. The system 400 comprises two NTTSs 202A-B for redundancy, preferably located in separate locations. Two TMCs 204A-B are directly certified by the NTTSs. The TMC 204A directly certifies a TLC 206A, while the TLC 204B directly certifies a TLC 206B. The TMC 204A also certifies another TMC 204C, which in turn certifies a TLC 206B, and similarly TMC 204B certifies TMC 204D, which in turn certifies TLC 206C. As illustrated, time certification logs are passed from the TMCs 206 up to the highest level TMCs 204 and then on to the NOC 210.

In the case that any clock fails, the device below that clock in the TTI can request service from an alternate dodo. If the NTTS 202A fails, for example, the TMC 204A can request certification from the NTTS 2028. Similarly, if the TMC 204A fails, the TLC 206A and the TMC 204C can request certification from the TMC 204C.

Applications 208A, 208B, and 208C request trusted time tokens from their respective TMCs. Upon receiving trusted time tokens, the applications then route verification requests to the NGC 210.

2.4 Application Bounded Time Service Another embodiment of the TTI system or a portion thereof may be configured as an application bounded time service. In application bounded time service, trusted time is provided to a specific application offered by a single third party.

For example, if Company X wants to sell certified e-mail gateway servers, each equipped with a TLC, the TLCs will be synchronized by TMCs operated by Company X. Company X's TMCs in turn are certified by TMCs of a trusted third party. Depending on the particular application, application bounded time service may require a separate NOC.

3. Calibration and Certification This section describes how clock calibration and certification is performed in the TTI. Individual timing elements in the TTI are enabled for operation when they possess a Time Calibration Certificate (TCCert). In the preferred embodiment, TMCs cannot issue trusted temporal tokens unless they have been issued a valid TCCert. Also in the preferred embodiment, a TMC cannot certify a lower clock unless the TMC has been issued a valid TCCert.

After measuring the calibration of a lower clock, an upper clock issues a TCCert to the lower clock to certify that the time of the lower clock is within a certain tolerance with respect to the upper dodo. The upper clock signs the TCCert to assure authenticity.

3.1 Procedural Overview Figure 5 illustrates an overview of the process by which a preferred embodiment of the TTI system generates trusted temporal tokens. The steps illustrated in Figure 5 are also depicted by the arrows between elements in Figure 3.

At a first step 502, the NTTS 202 certifies a TMC 204, sends a TCCert to the TMC 204, and records the certification locally. The TMC 204 then sends the TCCert to the TMC 210 for logging at a step 504. At this point, the TMC 204 possesses a valid TCCert and is capable of time certifying other lower clocks. At a step 506, the TMC 204 time certifies a TLC 206, sends a TCCert to the TLC 206, and records the certification. The TMC 204 also retrieves from the TLC 206 the number of trusted temporal tokens that the TLC 206 has issued since the last certification. This number is preferably used for billing purposes. At a step 508, the TLC 204 sends the TCCert and the token count of the TLC 206 to the NOC 210 for logging.

Once the TLC 206 has been certified, the TLC 206 is ready to issue trusted temporal tokens under its own TCCert. At a step 512, an application requests and the TLC 206 issues a new trusted temporal token. At a step 514, the application verifies the authenticity of the temporal token through the NOC, possibly at a future date.

3.2 TCCert Generation Figure 6 illustrates a preferred embodiment of the process by which an upper dodo certifies the time of a lower dodo, as in steps 502 and 506 of Figure 5. In the context of this illustration, an upper dodo is intended to represent the NTTS or a TMC, while a lower dodo is intended to represent another TMC or a TLC that is further down the chain of trusted time from the NTTS or the upper dodo. When a higher level clock measures the offset of a lower dodo and finds it within specified limits, a TCCert is created to record this determination. At a step 602, the lower dodo creates a TCCert Request (TCCertReq), which preferably comprises:

Upper Clock ID;
Lower Clock ID;
Lower Clock Accuracy;
Lower Clock Signature Parameters; and Lower Clock Signature (across above fields).

The lower dodo then sends the TCCertReq to the upper dodo. At a step 604 the upper dodo receives the TCCertReq from the lower dodo. The upper dodo validates the signature of the lower dodo and verifies that the lower dodo ID is correct at a step 606. At a step 608, the upper dodo measures the time offset of the lower dodo using Secure NTP (SNTP). The upper dodo determines whether the offset of the lower dodo is within acceptable limits at a step 610. If the lower dodo is within acceptable limits, control passes to a step 614. At the step 614, the upper dodo calibrates or adjusts and again measures the offset of the lower dodo if necessary. At a step 616, the upper dodo creates the TCCert by appending preferably the following fields to the TCCertReq:
To create the final TCCert, the upper clock appends its digital signature across the TCCertReq and the above-appended fields. By optionally including the TCCert of the upper clock in the TCCert of a lower clock, the complete trace of trusted time from the NTTS down to the lowest level can be encapsulated in each TCCert. At a step 618, the upper clock stores and records the TCCert and sends the TCCert to the lower clock.

If, at step 610, the time of the lower clock is found to be out of acceptable limits, it is possible that the clock has failed or has been tampered with. In this case, control passes to step 612. As step 612, the field TCCert Time is set so an illegal value, and the field Class of Service ID is set to ‘Out of Calibration’ if a lower clock has been found to be out of calibration, any TCCerts or trusted temporal tokens issued by the lower clock since its last TCCert issuance should be considered suspect.

Accordingly, the NOC 210 should be notified of the out of calibration measurement so that its database can reflect the invalidity of the previous TCCert and any trusted temporal tokens derived from it. If the NOC 210 has been notified of the out of calibration measurement, control is optionally passed back to step 614 for recalibration and recertification of the lower clock.

3.1 NTTS to TMC Calibration
The NTTS measures the clock offsets of the TMCs using PSTN connections and the SNTP protocol preferably once per day. The TMC clock offsets are expected to be within 10 milliseconds of UTC.

3.2 TMC to TLC Calibration Each TMC has a set of TLCs that it is responsible for certifying. Using SNTP, each TMC contacts each of the TLCs in its set once per day and requests its TCCert. If the received TCCert is less than 24 hours old, the TMC skid certification of that unit, closes the SNTP session and moves on to query the next TLC on its list. If the received TCCert is equal to or greater than 24 hours old, the TMC measures the TLC’s time offset, computes the time correction, and sends this correction to the TLC clock to keep it within specification. The offset is again measured, and if the TLC clock is within specification, the TMC issues a TCCert to the TLC stating that it is within a certain offset from UTC. It is expected that the TMC will certify the TLC to be within 100 ms of UTC.

3.3 Trusted Time Guarantee
The preferred embodiment of the TTI system combines a number of aspects to guarantee that the time stamp on a trusted temporal token has been derived from a source of time that is synchronized with an accepted standard, or that the TTI system provides a trusted time. The first aspect is that the physical devices of which the TTI system is comprised are either located in physically secure, trusted, facilities, or are designed to be physically tamper proof. The second aspect is that communications between elements in the TTI system are authenticated, and, if necessary, encrypted using the PKI system. The third aspect is that the time maintained by a TLC can be linked, through certifications using SNTP calibrations of a chain of trusted clocks, all the way to the NTTS or to another commonly accepted source of time. The fourth aspect is that each clock to be certified is specified to maintain at least a certain accuracy over the duration of a valid TCCert. Accordingly, each TCCert can guarantee that the certified clock’s time will be within its specified accuracy during the valid period of its TCCert plus the possible temporal variations introduced by the variations due to the accuracy of the foregoing certifying clocks during the valid periods of their respective TCCerts.

4. Trussed Temporal Token Generation and Verification
Once a TLC 206 has a valid TCCert, the TLC 206 is capable of issuing valid trusted temporal tokens. The tokens preferably include a concatenation of the data to be time-stamped and a time stamp supplied by a trusted source of time. In this case, the internal clock of the TLC 206. The signing of the complete message by the TLC 206 functions to bind the data to the time stamp such that the time stamp cannot be altered without
Once a token is generated, it is returned to the requesting application. The requesting application can then verify the authenticity of the token. In addition or in the alternative, the application may pass the token on to another application that may choose to verify the token again in the future.

An application can confirm the authenticity of the token by (1) checking with the NOC 210 that the issuing TLC 206 was in possession of a valid TCCert at the Time of token issue, and (2) verifying the signature of the token by obtaining, preferably from the NOC 210, a digital certificate containing the corresponding public key of the TLC 206.

5. Security Schemes

A number of different schemes can be used in conjunction with the disclosed TTI to ensure that the time stamp contained in a trusted temporal token is indeed derived from a source of trusted time. The schemes have varying advantages and disadvantages and balance increased security with increased verification, processing, and storage costs. The objective of these schemes is to ensure that a trusted temporal token has been issued by a TLC with a valid TCCert.

5.1 Basic Scheme A

A first security scheme relies upon the fact that a TLC has been issued a TCCert within a fixed period previous to the token issue in order to guarantee the validity of an issued time stamp. A TCCert is given a valid duration, such as, for example, seven days, during which the certified TLC can issue time stamps. If a TCCert expires or the TLC is issued a new TCCert, the old TCCert is destroyed by the TLC. In order to check the validity of a token, an application or the NOC 210 checks that the time of a time stamp corresponds to a valid period of the TCCert included in or referenced by the trusted temporal token. The NOC 210 must also check that the TCCert itself is valid by tracing the source of trusted time through additional TCCerts of higher clocks up to the NTTS 202.

5.2 Basic Scheme B

A variation of the previous scheme relies upon the alternative fact that a TLC was issued a valid TCCert within a certain time after issuing a trusted temporal token. In this case, TCCerts are considered valid for a fixed duration, such as seven days, before they are issued. Here, it is assumed if a TLC keeps time to within acceptable limits of NTTS time, the TLC has maintained this time for a reasonable period previous to the certification. In order to implement such a system, the TLCs would have to incorporate a reference to a TCCert that has not yet been issued in each trusted temporal token. The NOC 210 could then associate the references with the lacer issued TCCerts upon their issuance. The checking of trusted temporal tokens under this scheme could be achieved in a manner similar to the previous scheme.

5.3 High Trust Scheme A high trust scheme combines the aspects of Basic Schemes A and B above. In this scheme, the NOC checks that a TCCert has been issued to the issuing TLC within a fixed period before and within a fixed period after the Issuance of the trusted temporal token. In this case, the trusted temporal token need only contain a reference to the TCCert issued the TLC before the token issue. The NOC can then determine whether a subsequent TCCert has been issued within the requisite time period following the token issuance.

5.4 Alternative Scheme An alternative scheme provides a similar Uust guarantee to scheme A, particularly, that a TLC has
been issued a TCCert within a fixed period prior to issuing a trusted temporal token. This scheme, however, eliminates the
necessity of archiving all of the individual TCCerts for all of the TLCs in the TTI system.

Instead, each TCCert contains the complete TCCert of the issuing clock. In this manner, each TCCert will contain a complete,
authenticatable chain of certifications from the NTTS all the way down to the issuing TLC. Instead of cataloguing the TCCerts
of all of the individual clocks, each trusted temporal token will contain the complete chain of TCCerts linking the trusted time,
from which the token was derived, to the NTTS. The public keys of each of the certifying or issuing clocks would then be
made available through the CA 314 of the NOC 210, possibly using an Online Certificate Status Protocol (OCSP) responder
316, so that individual applications can independently verify the validity of trusted temporal tokens and the chain of trusted
time leading to its creation.

6. Business Model A billing scheme can also be integrated into the disclosed invention in order to facilitate the operation of the
TTI as part of an ongoing business concern. A number of different billing schemes providing various benefits can be used in
conjunction with the TTI system.

6.1 Per Stamp Billing The disclosed system provides mechanisms for TLCs to transmit to the NOC the number of time
stamps issued.

The NOC can be adapted to log this information and create billing reports for individual clients automatically. In this case
clients could be billed for each time stamp issued.

6.2 Flat Rate Certification An alternative scheme is based upon billing clients for time certification of each TLC located on the
clients’ premises.

In this case, a client pays for each issued TCCert and receives a flat rate on all of the time stamps issued during the valid
TCCert period. In this case, the NOC coordinates and automates billing procedures.

6.3 Charges for Verification In one business model, verification services for issued time stamps are provided free of charge to
any entity wanting to check the validity of a time stamp. Alternatively, verification services could be provided for a fee through
the NOC–C.

While certain exemplary preferred embodiments have been described and shown in the accompanying drawings, it is to be
understood that such embodiments are merely illustrative of and not restrictive on the broad invention. Further, it is to be
understood that this invention is not limited to the specific construction and arrangements shown and described since various
modifications or changes may occur to those of ordinary skill in the art without departing from the spirit and scope of the
invention as claimed. It is intended that the scope of the invention be limited not by this detailed description but by the claims
appended hereto.

CLASSIFICATIONS

| International Classification | G06F1/00, H04L9/32, G06F1/14, H04L9/10, G06F17/21, H04L29/06, G06F21/00, G06Q30/06 |
| Cooperative Classification   | H04L63/126, H04L63/0823, G06F2221/2151, H04L63/123, H04L2463/121, G06Q30/06, H04L2463/102, H04L63/12, G06F2221/2115, G06F21/725 |
| European Classification      | G06F21/72A, G06Q30/06, H04L63/12, H04L63/08C, H04L63/12A |

LEGAL EVENTS

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