

(74) **Agent: GRAHAM, Timothy**; IBM United Kingdom Limited, Intellectual Property Law, Hursley Park, Winchester Hampshire SO21 2JN (GB).

(81) **Designated States** (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

- with international search report (Art. 21(3))
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))

CACHELESS SESSION TICKET SUPPORT IN TLS INSPECTION

BACKGROUND OF THE INVENTION

Technical Field

[0001] This disclosure relates generally to information security on network-connected appliances.

Background of the Related Art

[0002] Security threats are continually evolving. With the rapid growth of cutting-edge web applications and increased file sharing, activities that may have been considered harmless in the past could become potential openings for attackers. Traditional security means, such as anti-malware software and firewalls, have become easier to bypass. Thus, there is a significant need for more advanced, proactive threat protection that can help provide comprehensive security against new and emerging threats.

[0003] Network-connected, non-display devices ("appliances") are ubiquitous in many computing environments. For example, appliances built purposely for performing traditional middleware service oriented architecture (SOA) functions are prevalent across certain computer environments. SOA middleware appliances may simplify, help secure or accelerate XML and Web services deployments while extending an existing SOA infrastructure across an enterprise. The utilization of middleware-purposed hardware and a lightweight middleware stack can address the performance burden experienced by conventional software solutions. In addition, the appliance form-factor provides a secure, consumable packaging for implementing middleware SOA functions. One particular advantage that these types of devices provide is to offload processing from back-end systems. To this end, it is well-known to use such middleware devices to perform computationally-expensive processes related to network security. For example, network intrusion prevention system (IPS) appliances are designed to sit at the entry points to an enterprise network to protect business-critical assets, such as internal networks, servers, endpoints and applications, from malicious threats.

[0004] The use of Secure Sockets Layer (SSL) and/or Transport Layer Security (TLS)-based encryption for network communications generally inhibits the ability to identify and mitigate threat traffic from within the network. It is now estimated that upwards of two-thirds or more of all business network traffic is conveyed over SSL/TLS. This means that organizations relying on network communications typically are unable to protect (from the network) the endpoints in their enterprise that may be susceptible to such threats. Indeed, the vast majority of SSL/TLS communications use only server authentication, i.e., the server is authenticated via the SSL/TLS protocols to the client, but the client is unauthenticated with respect to the server. This authentication asymmetry provides the opportunity for a process to interpose itself between client and server in such a way as to enable decryption of

communications and inspection of its contents. Such a “man-in-the-middle” (MITM) process may be malicious, or it may be used for legitimate reasons, such as packet inspection (for threat detection).

[0005] Thus, it is known to provide a transparent (MITM) proxy between a client and a server that can be configured to create and manage two separate SSL/TLS sessions, one as the client to the target server, and another as a server to the initiating client. The intermediate proxy thus appears to the server as a client, and to the client as the intended server. Communications initiated from the client, and any responses received from the server, theoretically are then available for inspection and subsequent action by a SSL/TLS inspector.

[0006] When performing man-in-the-middle inspection of a SSL/TLS connection, support by the SSL/TLS inspector of TLS session resumption is an important requirement. Conventionally, and as well-known, TLS servers provide session resumption to clients (irrespective of the MITM) according to one of two (2) distinct methods, namely Session ID (RFC 4507), and Session Ticket (RFC 5077). Session ID was the first mechanism invented to speed up the SSL/TLS handshake and to enable session resumption. In Session ID, all of the session information is stored on the server side. Session ID session resumption has several disadvantages, the foremost being that it is a performance bottleneck due to the requirement of spending time and space to lookup a given session ID when there are a large number of cached sessions. Another major drawback of Session ID is that one session ID can only work on one server, which makes a deployment very hard to scale unless session caches are synchronized across the servers. To address Session ID deficiencies, Session Ticket was developed. Session Ticket is a mechanism that enables the TLS server to resume sessions and avoid keeping per-client session state. To this end, the TLS server encapsulates the session state into a ticket and forward it to the client. The ticket is signed by service provider. The client can subsequently resume a session using the obtained ticket. When the server later receives a ticket and determines it is signed by the service provider, it will honor every setting stored in the ticket. Session Ticket is widely used among web servers due to its scalability and less resource overhead on the server side.

[0007] To support Session Ticket in TLS inspection (e.g., by a transparent MITM proxy), caching is necessary to maintain the mapping between ticket and session key. This is because there is no practical way to decrypt the session ticket, as the encryption mechanism is controlled by the application/service and not defined by the SSL/TLS specification. Maintaining session cache within the inspector, however, has several disadvantages, including poor scalability due to difficulty in distributing the session cache, limitations in session cache size due to storage and memory restrictions that can cause the proxy to run out of cache, CPU bounds that complicate cache loop-up time and that limit the type of hash algorithms that can be implemented for mapping the session tickets, as well as vulnerability to denial-of-service attack by an attacker who could intentionally flush out entries in the session cache and thereby bypass inspection.

[0008] There remains to provide TLS session resumption in a TLS inspector that provides Session Ticket support but that overcomes these and related deficiencies in prior approaches.

[0009] Therefore, there is a need in the art to address the aforementioned problem.

BRIEF SUMMARY

[0010] Viewed from a first aspect, the present invention provides a method operative within an intermediary positioned between a Transport Layer Security (TLS) client and a TLS server and that provides a TLS inspection function during a TLS session, comprising: upon receipt from the TLS server of an original session ticket, generating a new session ticket; applying an encryption function to the new session ticket; outputting to the TLS client the encrypted new session ticket; upon receipt from the TLS client of the encrypted new session ticket, decrypting the encrypted new session ticket to recover the original session ticket and the session context information; and using the recovered original session ticket and the session context information to resume the TLS session.

[0011] Viewed from a further aspect, the present invention provides an apparatus, comprising: a processor; computer memory holding computer program instructions executed by the processor, the computer program instructions comprising program code configured: upon receipt from the TLS server of an original session ticket, to generate a new session ticket; to apply an encryption function to the new session ticket; to output to the TLS client the encrypted new session ticket; upon receipt from the TLS client of the encrypted new session ticket, to decrypt the encrypted new session ticket to recover the original session ticket and the session context information; and to use the recovered original session ticket and the session context information to resume the TLS session.

[0012] Viewed from a further aspect, the present invention provides a computer program product for a Transport Layer Security (TLS) inspection function during a TLS session, the computer program product comprising a computer readable storage medium readable by a processing circuit and storing instructions for execution by the processing circuit for performing a method for performing the steps of the invention.

[0013] Viewed from a further aspect, the present invention provides a computer program stored on a computer readable medium and loadable into the internal memory of a digital computer, comprising software code portions, when said program is run on a computer, for performing the steps of the invention.

[0014] Viewed from a further aspect, the present invention provides an apparatus positioned between a Transport Layer Security (TLS) client and a TLS server, comprising: a hardware processor, and computer memory holding computer program instructions configured as a cacheless TLS inspector mechanism to: receive a session ticket from the TLS server and, in response: (a) generate a composite session ticket, and (b) output to the TLS

client the composited session ticket in lieu of caching the session ticket, and receive the composited session ticket from the TLS client and, in response: (c) recover the session ticket, and (d) use the recovered session ticket to resume a session with the TLS server.

[0015] A network-based appliance includes a mechanism to enable the appliance to provide TLS inspection with session resumption, but without requiring that a session cache be maintained in the inspector. To this end, the inspector is configured without a session cache and thus no longer maintains the mapping between a session ticket (received from the TLS server) and the session context. Instead, the inspector is configured in such a way as to cause the TLS client to participate in maintaining the session context, in effect on behalf of the TLS inspector. In operation, when the inspector first receives the session ticket from the TLS server, and in lieu of caching it, the inspector generates and issues to the client a composited ticket that includes the original ticket and session context information that contains one or more session keys. Typically, there are two session keys, one for the client-side, and one for the server-side. The composited ticket (or composited session ticket) preferably is encrypted by the inspector to secure the session information. When the TLS client presents the composited session ticket (back to the inspector) to resume the TLS connection, the inspector decrypts the ticket and retrieves the session context from it directly. The inspector then uses the original session ticket to resume the TLS session to the TLS server. This approach obviates any cache lookup or even the requirement to maintain local session cache at the TLS inspector. Rather, in effect the composited ticket becomes the cache for the session ticket itself.

[0016] Generalizing, and according to a first aspect of this disclosure, a method is operative within an intermediary positioned between a client and a server and that provides a TLS inspection function. Upon receipt from the TLS server of an original session ticket, and instead of caching the original session ticket in a session cache, a new session ticket is generated. The new session ticket comprises a value derived by applying a transform function to the original session ticket and the session context information (namely, the cipher suite, master key, and the like negotiated for use during the session). The transform function may vary. A representative transform function concatenates the session context information to the original session ticket. An encryption function is then applied to the new session ticket (sometimes referred to herein as a composited session ticket) to secure the session information. The encrypted transformed session ticket is then delivered to the requesting TLS client. When that ticket is later received back from the TLS client, it is decrypted to recover the original session ticket and the session context information. Using the information recovered, the TLS session is then resumed with the TLS server.

[0017] According to a second aspect of this disclosure, an apparatus is positioned between a Transport Layer Security (TLS) client and a TLS server to provide a TLS inspection function during a TLS session. The apparatus comprises a set of one or more hardware processors, and computer memory holding computer program instructions executed by the hardware processors to perform a set of operations such as the method steps described above.

[0018] According to a third aspect of this disclosure, a computer program product in a non-transitory computer readable medium for use in a data processing system is described. The data processing system is positioned between a Transport Layer Security (TLS) client and a TLS server to provide a TLS inspection function during a TLS session. The computer program product holds computer program instructions executed in the data processing system and configured to perform operations such as the method steps described above.

[0019] The foregoing has outlined some of the more pertinent features of the disclosed subject matter. These features should be construed to be merely illustrative. Many other beneficial results can be attained by applying the disclosed subject matter in a different manner or by modifying the subject matter as will be described.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] For a more complete understanding of the subject matter and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

FIG. 1 depicts an exemplary block diagram of a distributed data processing environment in which exemplary aspects of the illustrative embodiments may be implemented;

FIG. 2 is an exemplary block diagram of a data processing system in which exemplary aspects of the illustrative embodiments may be implemented;

FIG. 3 illustrates an exemplary network-based secure appliance in which the disclosed subject matter may be implemented;

FIG. 4 illustrates how a conventional SSL/TLS communication is processed in a man-in-the-middle appliance to facilitate inspection of secure traffic;

FIG. 5 illustrates TLS session resumption using a TLS inspector that incorporates a session cache; and

FIG 6 depicts TLS session resumption according to the subject matter of this disclosure wherein the TLS inspector provides cacheless session ticket support.

DETAILED DESCRIPTION OF AN ILLUSTRATIVE EMBODIMENT

[0021] With reference now to the drawings and in particular with reference to FIGs. 1-2, exemplary diagrams of data processing environments are provided in which illustrative embodiments of the disclosure may be implemented. It should be appreciated that FIGs. 1-2 are only exemplary and are not intended to assert or imply any limitation with regard to the environments in which aspects or embodiments of the disclosed subject matter may be implemented. Many modifications to the depicted environments may be made without departing from the scope of the present invention.

Client-server technologies

[0022] With reference now to the drawings, FIG. 1 depicts a pictorial representation of an exemplary distributed data processing system in which aspects of the illustrative embodiments may be implemented. Distributed data processing system 100 may include a network of computers in which aspects of the illustrative embodiments may be implemented. The distributed data processing system 100 contains at least one network 102, which is the medium used to provide communication links between various devices and computers connected together within distributed data processing system 100. The network 102 may include connections, such as wire, wireless communication links, or fiber optic cables.

[0023] In the depicted example, server 104 and server 106 are connected to network 102 along with storage unit 108. In addition, clients 110, 112, and 114 are also connected to network 102. These clients 110, 112, and 114 may be, for example, personal computers, network computers, or the like. In the depicted example, server 104 provides data, such as boot files, operating system images, and applications to the clients 110, 112, and 114. Clients 110, 112, and 114 are clients to server 104 in the depicted example. Distributed data processing system 100 may include additional servers, clients, and other devices not shown.

[0024] In the depicted example, distributed data processing system 100 is the Internet with network 102 representing a worldwide collection of networks and gateways that use the Transmission Control Protocol/Internet Protocol (TCP/IP) suite of protocols to communicate with one another. At the heart of the Internet is a backbone of high-speed data communication lines between major nodes or host computers, consisting of thousands of commercial, governmental, educational and other computer systems that route data and messages. Of course, the distributed data processing system 100 may also be implemented to include a number of different types of networks, such as for example, an intranet, a local area network (LAN), a wide area network (WAN), or the like. As stated above, FIG. 1 is intended as an example, not as an architectural limitation for different embodiments of the disclosed subject matter, and therefore, the particular elements shown in FIG. 1 should not be considered limiting with regard to the environments in which the illustrative embodiments of the present invention may be implemented.

[0025] With reference now to FIG. 2, a block diagram of an exemplary data processing system is shown in which aspects of the illustrative embodiments may be implemented. Data processing system 200 is an example of a computer, such as client 110 in FIG. 1, in which computer usable code or instructions implementing the processes for illustrative embodiments of the disclosure may be located.

[0026] With reference now to FIG. 2, a block diagram of a data processing system is shown in which illustrative embodiments may be implemented. Data processing system 200 is an example of a computer, such as server 104 or client 110 in FIG. 1, in which computer-usable program code or instructions implementing the processes may be located for the illustrative embodiments. In this illustrative example, data processing system 200

includes communications fabric 202, which provides communications between processor unit 204, memory 206, persistent storage 208, communications unit 210, input/output (I/O) unit 212, and display 214.

[0027] Processor unit 204 serves to execute instructions for software that may be loaded into memory 206. Processor unit 204 may be a set of one or more processors or may be a multi-processor core, depending on the particular implementation. Further, processor unit 204 may be implemented using one or more heterogeneous processor systems in which a main processor is present with secondary processors on a single chip. As another illustrative example, processor unit 204 may be a symmetric multi-processor (SMP) system containing multiple processors of the same type.

[0028] Memory 206 and persistent storage 208 are examples of storage devices. A storage device is any piece of hardware that is capable of storing information either on a temporary basis and/or a permanent basis. Memory 206, in these examples, may be, for example, a random access memory or any other suitable volatile or non-volatile storage device. Persistent storage 208 may take various forms depending on the particular implementation. For example, persistent storage 208 may contain one or more components or devices. For example, persistent storage 208 may be a hard drive, a flash memory, a rewritable optical disk, a rewritable magnetic tape, or some combination of the above. The media used by persistent storage 208 also may be removable. For example, a removable hard drive may be used for persistent storage 208.

[0029] Communications unit 210, in these examples, provides for communications with other data processing systems or devices. In these examples, communications unit 210 is a network interface card. Communications unit 210 may provide communications through the use of either or both physical and wireless communications links.

[0030] Input/output unit 212 allows for input and output of data with other devices that may be connected to data processing system 200. For example, input/output unit 212 may provide a connection for user input through a keyboard and mouse. Further, input/output unit 212 may send output to a printer. Display 214 provides a mechanism to display information to a user.

[0031] Instructions for the operating system and applications or programs are located on persistent storage 208. These instructions may be loaded into memory 206 for execution by processor unit 204. The processes of the different embodiments may be performed by processor unit 204 using computer implemented instructions, which may be located in a memory, such as memory 206. These instructions are referred to as program code, computer-usable program code, or computer-readable program code that may be read and executed by a processor in processor unit 204. The program code in the different embodiments may be embodied on different physical or tangible computer-readable media, such as memory 206 or persistent storage 208.

[0032] Program code 216 is located in a functional form on computer-readable media 218 that is selectively removable and may be loaded onto or transferred to data processing system 200 for execution by processor unit 204. Program code 216 and computer-readable media 218 form computer program product 220 in these examples. In one example, computer-readable media 218 may be in a tangible form, such as, for example, an optical or magnetic disc that is inserted or placed into a drive or other device that is part of persistent storage 208 for transfer onto a storage device, such as a hard drive that is part of persistent storage 208. In a tangible form, computer-readable media 218 also may take the form of a persistent storage, such as a hard drive, a thumb drive, or a flash memory that is connected to data processing system 200. The tangible form of computer-readable media 218 is also referred to as computer-recordable storage media. In some instances, computer-recordable media 218 may not be removable.

[0033] Alternatively, program code 216 may be transferred to data processing system 200 from computer-readable media 218 through a communications link to communications unit 210 and/or through a connection to input/output unit 212. The communications link and/or the connection may be physical or wireless in the illustrative examples. The computer-readable media also may take the form of non-tangible media, such as communications links or wireless transmissions containing the program code. The different components illustrated for data processing system 200 are not meant to provide architectural limitations to the manner in which different embodiments may be implemented. The different illustrative embodiments may be implemented in a data processing system including components in addition to or in place of those illustrated for data processing system 200. Other components shown in FIG. 2 can be varied from the illustrative examples shown. As one example, a storage device in data processing system 200 is any hardware apparatus that may store data. Memory 206, persistent storage 208, and computer-readable media 218 are examples of storage devices in a tangible form.

[0034] In another example, a bus system may be used to implement communications fabric 202 and may be comprised of one or more buses, such as a system bus or an input/output bus. Of course, the bus system may be implemented using any suitable type of architecture that provides for a transfer of data between different components or devices attached to the bus system. Additionally, a communications unit may include one or more devices used to transmit and receive data, such as a modem or a network adapter. Further, a memory may be, for example, memory 206 or a cache such as found in an interface and memory controller hub that may be present in communications fabric 202.

[0035] Computer program code for carrying out operations of the present invention may be written in any combination of one or more programming languages, including an object-oriented programming language such as Java™, Smalltalk, C++, C#, Objective-C, or the like, and conventional procedural programming languages. The program code may execute entirely on the user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer, or entirely on the remote computer or server. In the latter scenario, the remote computer may be connected to the user's computer through

any type of network, including a local area network (LAN) or a wide area network (WAN), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider). Java and all Java-based trademarks and logos are trademarks or registered trademarks of Oracle and/or its affiliates.

[0036] Those of ordinary skill in the art will appreciate that the hardware in FIGs. 1-2 may vary depending on the implementation. Other internal hardware or peripheral devices, such as flash memory, equivalent non-volatile memory, or optical disk drives and the like, may be used in addition to or in place of the hardware depicted in FIGs 1-2. Also, the processes of the illustrative embodiments may be applied to a multiprocessor data processing system, other than the SMP system mentioned previously, without departing from the scope of the disclosed subject matter.

[0037] As will be seen, the techniques described herein may operate in conjunction within the standard client-server paradigm such as illustrated in FIG. 1 in which client machines communicate with an Internet-accessible Web-based portal executing on a set of one or more machines. End users operate Internet-connectable devices (e.g., desktop computers, notebook computers, Internet-enabled mobile devices, or the like) that are capable of accessing and interacting with the portal. Typically, each client or server machine is a data processing system such as illustrated in FIG. 2 comprising hardware and software, and these entities communicate with one another over a network, such as the Internet, an intranet, an extranet, a private network, or any other communications medium or link. A data processing system typically includes one or more processors, an operating system, one or more applications, and one or more utilities. The applications on the data processing system provide native support for Web services including, without limitation, support for HTTP, SOAP, XML, WSDL, UDDI, and WSFL, among others. Information regarding SOAP, WSDL, UDDI and WSFL is available from the World Wide Web Consortium (W3C), which is responsible for developing and maintaining these standards; further information regarding HTTP and XML is available from Internet Engineering Task Force (IETF). Familiarity with these standards is presumed.

[0038] As further background, Secure Sockets Layer/Transport Layer Security (SSL/TLS) is a well-known cryptographic protocol that is used to secure communications over networks such as the Internet. Cryptographic protocols such as SSL/TLS are often based on public key cryptographic systems, such as the RSA (Rivest, Shamir and Adelman) encryption algorithm. For a traditional RSA-based SSL session, the two sides of a connection agree upon a "pre-master secret" (PMS) which is used to generate the parameters for the remainder of the session. Typically, the two sides use RSA asymmetric encryption to establish the pre-master secret without exchanging the actual value in plaintext. In operation, the SSL client generates the pre-master secret and encrypts it with the SSL server's publicly available RSA key. This generates an encrypted pre-master secret (ePMS), which is then provided to the SSL server. The SSL server has a private decryption key, which is then used to decrypt the encrypted pre-master secret. At this point, both the client and the server have the original pre-master secret and can use it to generate the symmetric key used for actual encrypted and secure data exchange

[0039] Encrypted traffic on the web occurs by a chain of trust. Each web server has a certificate that is presents to each client (usually a web browser) to indicate that they are who they say they are. Web servers often get these certificates from an authority (a Certificate Authority, or CA) that can vouch for the legitimacy of the web server. The server's certificate indicates the authority from which the certificate was obtained (the "issuer"). Web browsers typically have a list of issuers that they trust. When a web browser is presented with a certificate from a web server, the browser will check the issuer and match it against its trusted list. If a match is found, the connection will continue; if a match is not found, the browser usually will present a warning and perhaps reject the connection. A CA is not necessarily a special entity other than the fact that it is trusted. Any entity can set itself up to trust, or sign, certificates. A certificate can trust itself, which is referred to as a self-signed certificate. To interoperate with a client using SSL/TLS, it is necessary to create certificates that the client will implicitly trust. With respect to a network appliance (as described below), it is presumed that an administrator can configure enterprise clients to trust the appliance to sign certificates. In effect, the issuer of the appliance then is on the browser's list of trusted issuers.

Network-connected secure appliances

[0040] A network appliance typically is a rack-mounted device. The device includes physical security that enables the appliance to serve as a secure vault for sensitive information. Typically, the appliance is manufactured, pre-loaded with software, and then deployed within or in association with an enterprise or other network operating environment; alternatively, the box may be positioned locally and then provisioned with standard or customized middleware virtual images that can be securely deployed and managed, e.g., within a private or an on premise cloud computing environment. The appliance may include hardware and firmware cryptographic support, possibly to encrypt data on hard disk. No users, including administrative users, can access any data on physical disk. In particular, preferably the operating system (e.g., Linux ®) locks down the root account and does not provide a command shell, and the user does not have file system access. Typically, the appliance does not include a display device, a CD or other optical drive, or any USB, Firewire or other ports to enable devices to be connected thereto. It is designed to be a sealed and secure environment with limited accessibility and then only be authenticated and authorized individuals. Linux is a registered trademark of Linus Torvalds in the United States, other countries, or both.

[0041] Referring to FIG. 3, a representative operating environment includes the physical appliance 300, which interfaces to a network 302. The appliance may be implemented using a data processing system such as described above with respect to FIG. 2, and it may represent one of the servers (or clients) shown in FIG. 1. Typically, the appliance 300 includes a Web 2.0-based user interface (UI), a command line interface (CLI), and REST-based application programming interfaces (APIs). In this example, the appliance has been provisioned with an image comprising an operating system 304, an application server 306, an HTTP server 308, and other application programs 310. Additional software solutions (not shown) may be included within the image. These

software elements may come pre-loaded on the appliance, which may include other data (e.g., templates, scripts, files, etc.). The particular software configuration of course will depend on the use being made of the appliance. The appliance includes one or more storage devices (e.g., disk 315). The type and number of storage devices may vary.

Interception, decryption and inspection of secure network communications

[0042] By way of further background, FIG. 4 illustrates the basic operation of a known man-in-the-middle (MITM) device 400 for intercepting, decrypting and inspecting secure network communications according to a known technique. The device is implemented within a secure network appliance such as described above and illustrated in FIG. 3. More generally, the device is a computing system such as shown in FIG. 1.

[0043] As illustrated, the device 400 is connected between a client 402 and a server 404. The client and server are provisioned to secure communications using SSL or TLS. Familiarity with SSL/TLS is presumed. In this embodiment, the device 400 provides a transparent (or man-in-the-middle) proxy between the client 402 and the server 404 by creating and managing two (2) separate SSL/TLS sessions, one as a client process X_{ss} 406 to the target server 404, and another as a server process X_{cs} 408 to the initiating client 402. The X_{ss} and X_{cs} components are sometimes referred to herein as SSL instances, where an SSL instance typically is a piece of code that makes up an SSL session. An SSL session (or session context) is the communication itself that occurs between two endpoints. The intermediate proxy 400 thus appears to the server 404 as a client, and to the client 402 as the intended server. Communications initiated from the client 402, and any responses received from the server 404, are then available for inspection (or other processing, such as rewrite) and subsequent action. To that end, the device 400 may include a protocol analysis module (e.g., IBM® Security Network Protection PAM), which provides a packet inspection function to identify and possibly mitigate network threats. The particular details of the module (or other packet inspection applications that may be supported) are not an aspect of this disclosure.

[0044] In operation, and as seen in FIG. 4, following an initial TCP handshake (not shown), the client 402 generates the SSL/TLS session initiation request message (hereafter referred to as the "Client Hello") to begin the SSL/TLS handshake to the server. This is step 1. The proxy intercepts this connection and directs it to the client-facing server component X_{cs} 408. At step 2, the X_{cs} component reads the Client Hello, interprets the data, and responds to the client 402, typically with a server hello message, a certificate, and a server done message. In step 3, a brand new SSL connection is configured and setup inside the appliance. This is a server-facing connection that is initiated by the X_{ss} . The X_{ss} then generates a new Client Hello (referred to here as ClientHello2 to distinguish it from the ClientHello in step 1), and sends the (new) Client Hello to the server. In step 4, the server 404 reads the new Client Hello and responds with ServerHello2, Certificate2 and ServerDone2. These messages are yet again distinct from the messages issued by X_{cs} to the client in step 2. As a result, there are two (2) distinct connections, one between the client 402 and X_{cs} 408, and the other between X_{ss} 406 and the server 404. At this

point, if the MITM processing (e.g., by the PAM or other application) determines that this is not a (client-server) connection is desired to be inspected, the system either must continue to inspect the connection (perhaps ignoring the results), or shut it down entirely. The determination may be based in any convenient manner, e.g., by performing a policy-based rule match against information in the certificate received from the server (Certificate2 above).

Cacheless session ticket support in TLS inspection

[0045] With the above as background, the cacheless session ticket support in TLS inspection of this disclosure is now described. Familiarity with TLS Session Ticket according to Internet RFC 5077 is presumed. A representative commercial product in which the technique may be implemented is IBM® QRadar® Network Security (XGS) (formerly known as IBM Security Network Protection (XGS)), a next-generation intrusion prevention system (IPS). Of course, the identification of this commercial product is not intended to be limiting, as the approach may be carried out in any intermediary device, appliance, product or system. IBM and QRadar are trademarks of International Business Machines Corporation, registered in many jurisdictions worldwide.

[0046] As noted above, and according to this disclosure, a network-based appliance such as described includes a mechanism to enable the appliance to provide TLS inspection with session resumption, but without requiring that a session cache be maintained in the inspector. To this end, the inspector is configured without a session cache (or, in the alternative, with a cache that is not used) and thus no longer maintains the mapping between a session ticket (received from the TLS server) and the session context. Instead, the inspector is configured in such a way as to cause the TLS client to participate in maintaining the session context, in effect on behalf of the TLS inspector. In operation, when the inspector first receives the session ticket from the TLS server, and in lieu of caching it, the inspector generates and issues to the client a composited ticket that includes the original ticket and session context information that contains the session key. The composited ticket (or composited session ticket) preferably is encrypted by the inspector to secure the session information. When the TLS client presents the composited session ticket (back to the inspector) to resume the TLS connection, the inspector decrypts the ticket and retrieves the session context from it directly. The inspector then uses the original session ticket to resume the TLS session. This approach obviates any cache lookup or even the requirement to maintain local session cache at the TLS inspector. Rather, in effect the composited ticket becomes the cache for the session ticket itself.

[0047] As is well-known, it is assumed that the appliance includes a mechanism to enable the MITM process (whether proxy-based or otherwise) to resume the original connection and to re-connect the original endpoints (without inspecting), e.g., upon a rule match against a server certificate or otherwise. Session Ticket in TLS support is used for this purpose.

[0048] FIG. 5 depicts a flow diagram showing conventional Session Ticket in TLS, namely, with an inspector 500 that includes a session cache. Familiarity with standard TLS handshaking semantics is presumed. As shown, the flow diagram in FIG. 5 illustrates the inspector located intermediate the TLS client 502 and the TLS server 504. In the conventional TLS handshake flow, client 502 issues a Client Hello to the server 504. This is step 506. At step 508, the server 504 responds with various messages, namely, the Server Hello, the Certificate, the ServerKeyExchange, and the ServerHelloDone. The session context information (cipher suites, master key, etc.) is stored by the inspector 500 at step 510. At step 512, the client 502 returns to the server various messages, namely, the ClientKeyExchange, an optional ChangeCipherSpec, and Finished. Server 504 then responds with another set of messages, namely, NewSessionTicket, any response to the ChangeCipherSpec message (if sent by the client), and Finished. This completes the initial TLS handshake. At step 516, the inspector 500 stores the new ticket in its local cache. In use, and as depicted at step 518, application data flows between client 502 and the server 504. The inspector 500 uses the session information in the ticket to decrypt payloads, as depicted at step 520, to perform one or more inspector functions. The inspector also passes the session ticket back to the client.

[0049] One or more operations by the inspector interrupt the session, thus requiring the ability of the inspector to carry out session resumption. To that end, and as depicted at step 522, it is assumed that the client issues another Client Hello, this time passing the session ticket. At step 524, the inspector performs a lookup for the session ticket in its local cache. If the ticket is matched, the inspector 500 issues a new Client Hello to the server, passing the session ticket. This is step 526. At step 528, the server 504 responds with various messages, namely, the Server Hello, the Certificate, the optional ChangeCipherSpec, and Finished. At step 530, the client 502 then responds with a set of messages, namely, any response to the ChangeCipherSpec message (if sent by the server), and Finished. This completes the follow-on TLS handshake that would be needed for session resumption. At step 532, the inspector 500 obtains the one or more session keys (stored at step 510) from its cache. Typically, there are two session keys, one for each session (client ↔ inspector, and inspector ↔ server). As application data is then passed between client and server (step 532), the inspector uses the session keys to decrypt payloads as necessary. This is step 534.

[0050] FIG. 6 is similar to FIG. 5, but this drawing depicts the changes to the conventional session caching approach according to the technique of this disclosure. As has been described, the modified technique provides for “cacheless” Session Ticket support in TLS inspection. To this end, the inspector is configured such that it no longer maintains the mapping between a session ticket (received from the TLS server) and the session context. Instead, the inspector is configured to cause the TLS client to participate in maintaining the session context, in effect on behalf of the TLS inspector. This approach obviates any cache lookup or even the requirement to maintain local session cache at the TLS inspector. Rather, in effect the interactions between the inspector and the client provide a way for the inspector to offload the caching from its own session cache and onto the requesting client, which ends up storing (albeit in an altered form) the session ticket. In effect, the client becomes the cache for the session ticket itself.

[0051] In operation, when the inspector first receives the session ticket from the TLS server, and in lieu of caching it, the inspector generates and issues to the client a composited ticket that includes the original ticket and session context information that contains the session key. The composited ticket (or composited session ticket) preferably is encrypted by the inspector to secure the session information. When the TLS client presents the composited session ticket (back to the inspector) to resume the TLS connection, the inspector decrypts the ticket and retrieves the session context from it directly. The inspector then uses the original session ticket to resume the TLS session to the TLS server.

[0052] The cacheless session ticket support is depicted in FIG. 6. Once again, the inspector 600 is shown positioned intermediate between the TLS client 602 and the TLS server 604. Unlike FIG. 5, the inspector 600 need not incorporate a session cache. As in the conventional TLS handshake flow, client 602 issues a Client Hello to the server 604. This is step 606. At step 608, the server 404 responds with various messages, namely, the Server Hello, the Certificate, the ServerKeyExchange, and the ServerHelloDone. Once again, the session context information (cipher suites, master key, etc.) is stored by the inspector 600 at step 610. At step 612, the client 602 returns various messages, namely, the ClientKeyExchange, an optional ChangeCipherSpec, and Finished. This time, however, those messages are intercepted by the inspector instead of being passed through to the server (as in FIG. 5). At step 614, the server 604 provides the NewSessionTicket message, an optional ChangeCipherSpec message, and a Finished message. The NewSessionTicket includes an original session ticket. At step 616, and in lieu of storing the original session ticket provided by the server 604 (and as in step 516 in FIG. 5), the inspector 600 generates a new session ticket, referred to as [A]. Further details of a preferred technique for generating the new session ticket are described below. The inspector 600 then outputs to the client 602 a set of messages, namely, NewSessionTicket[A], an optional ChangeCipherSpec, and Finished. This is step 618. The NewSessionTicket[A] message include the new session ticket [A]. At step 620, application data flows between client 602 and server 604. The inspector 600 uses the session information in the ticket to decrypt payloads, as depicted at step 622, to perform one or more inspector functions.

[0053] As before, one or more operations by the inspector interrupt the session, thus requiring the ability of the inspector 600 to carry out session resumption. To that end, and as depicted at step 624, it is assumed that the client issues another Client Hello, this time passing back to the inspector the new session ticket [A]. At step 626, the inspector 600 decrypts new session ticket [A] to recover the original session ticket (referred to as [B]), and to recover the session information. At step 628, the inspector 600 replaces Ticket [A] with Ticket [B] in the Client Hello and, at step 630, the inspector 600 sends the Client Hello (with Session Ticket [B] to the server 604. At step 632, the server 604 responds with various messages, namely, the Server Hello, the Certificate, the ChangeCipherSpec, and Finished. At step 634, the client 502 then responds with a set of messages, namely, the ChangeCipherSpec, and Finished. This completes the follow-on TLS handshake that would be needed for session resumption. At step 636, the inspector 560 obtains the session keys from the session information extracted from

Ticket [A] at step 626. As application data is then passed between client and server (step 638), the inspector 600 uses the session key to decrypt payloads as necessary. This is step 640.

[0054] Summarizing, and as can be seen by comparing steps 514, 516 and 524 in FIG. 5 with steps 616, 618 and 626 in FIG. 6, the approach herein obviates caching the session ticket in the inspector itself. Rather, when the inspector first receives the session ticket from the TLS server, and in lieu of caching it, the inspector generates and issues to the client a composited ticket that includes the original ticket and session context information that contains the session key. The composited ticket (or composited session ticket) preferably is encrypted by the inspector to secure the session information. When the TLS client presents the composited session ticket (back to the inspector) to resume the TLS connection, the inspector decrypts the ticket and retrieves the session context from it directly. The inspector then uses the original session ticket to resume the TLS session to the TLS server.

[0055] The following describes a preferred technique for generating the new session ticket. This is step 616 in FIG. 6. Preferably, the new session ticket is generated as follows:

Encrypt (Transform (Original Session Ticket, Session Information), Encryption Key) where Session Information includes cryptographic information such as cipher suite(s), a master key, etc.), the Transform is any method or computation to combine together the identified data, namely, Original Session Ticket, Session Information, and Encrypt refers to any cryptographic algorithm that can protect the new session ticket. A typical Transform may be a concatenation operation, but this is not a limitation, as more complex computational methods may be applied for the transformation. Of course, a transformation must have an associated inverse so that the original data can be recovered. For the encryption wrapper, a typical solution might utilize public key cryptography, such that the Encryption Key is a public key having an associated private or secret key that is used for decryption when the new session ticket is later received from the client. Thus, and as described above, the new session ticket is generated by first applying the transform function to the original session ticket and session context information associated with the TLS session, with an encryption function then applied to the result of the transformation. The result of applying the transform is sometimes referred to herein as a "composited" session ticket, or New Session Ticket. The inspector outputs to the client the encrypted new session ticket.

[0056] When the inspector receives the encrypted New Session Ticket from the client in the follow-on Client Hello, the session is resumed by the inspector decrypting the ticket to obtain (recover) the Original Session Ticket, Session Information, and then replacing the in the Client Hello with the Original Session Ticket. As noted above, preferably the decryption is carried out using the private key of the public key pair maintained at the inspector. There are preferably two decryption operations, namely: Get_Ticket (Decrypt (New Session Ticket), and Get_SessionInfo (Decrypt (New Session Ticket). If the decryption is successful, the decrypted payload should contain the Original Session Ticket and the Session Information. The Get_Ticket function obtains/recovers the Original Session Ticket and Get_SessionInfo obtains the session information, such as the master TLS key, necessary to decrypt the payloads.

[0057] The above-described approach provides many advantages. Current TLS inspector mechanisms that provide TLS Session Ticket support have several disadvantages that are overcome by the described approach. Foremost, there is no requirement to maintain a session cache in the inspector. As a consequence, the known disadvantages of that approach (poor scalability, processing and memory inefficiencies, and potential for Denial of Service (DoS) exploitation) are overcome. This approach is simple to implement, as the additional functions can be implemented readily in a computationally-efficient manner. The approach is highly reliable and secure. By off-loading caching of the session tickets themselves, the approach provides for better performance of the inspector mechanism, thereby enhancing the overall operation of the intermediary.

[0058] The techniques herein also facilitate scaling of the TLS support infrastructure. Thus, e.g., when multiple inspectors are implemented, as long as the transform function is synchronized across the inspectors preferably in advance (e.g., by sharing the key needed to decrypt the composite ticket), every inspector can understand the composite session ticket and then resume the inspection.

[0059] While the techniques have been described in the context of a proxy, this is not a limitation. Generalizing, the processing described herein may be carried in any intermediary positioned between client and server. In one such embodiment, the intermediary provides transparent inline content inspection and modification. The client and server are computing entities (endpoints). The intermediary may be configured as a physical device, a virtual device, or some combination thereof. It can be used for a number of different applications including, without limitation, the decrypting of encrypted (SSL/TLS) sessions so that security inspection can be performed in the manner previously described.

[0060] While a preferred operating environment and use case (a secure appliance) has been described, the techniques herein may be used in any other operating environment in which it is desired to intercept, decrypt, inspect and/or modify (rewrite) network traffic to and/or from a computing system or device.

[0061] As has been described, the functionality described above may be implemented as a standalone approach, e.g., a software-based function executed by a processor, or it may be available as a service (including as a web service via a SOAP/XML interface). The particular hardware and software implementation details described herein are merely for illustrative purposes and are not meant to limit the scope of the described subject matter.

[0062] More generally, computing devices within the context of the disclosed subject matter are each a data processing system (such as shown in FIG. 2) comprising hardware and software, and these entities communicate with one another over a network, such as the Internet, an intranet, an extranet, a private network, or any other communications medium or link. The applications on the data processing system provide native support for Web and other known services and protocols including, without limitation, support for HTTP, FTP, SMTP, SOAP, XML, WSDL, UDDI, and WSFL, among others. Information regarding SOAP, WSDL, UDDI and WSFL is available from

the World Wide Web Consortium (W3C), which is responsible for developing and maintaining these standards; further information regarding HTTP, FTP, SMTP and XML is available from Internet Engineering Task Force (IETF). Familiarity with these known standards and protocols is presumed.

[0063] The techniques described herein may be implemented in or in conjunction with various client-side architectures (e.g., firewalls, NAT devices), and in or in conjunction with various server-side architectures including simple n-tier architectures, web portals, federated systems, and the like. The techniques herein may be practiced in a loosely-coupled server (including a "cloud"-based) environment.

[0064] Still more generally, the subject matter described herein can take the form of an entirely hardware embodiment, an entirely software embodiment or an embodiment containing both hardware and software elements. In a preferred embodiment, the trusted platform module function is implemented in software, which includes but is not limited to firmware, resident software, microcode, and the like. Furthermore, the download and delete interfaces and functionality can take the form of a computer program product accessible from a computer-usable or computer-readable medium providing program code for use by or in connection with a computer or any instruction execution system. For the purposes of this description, a computer-usable or computer readable medium can be any apparatus that can contain or store the program for use by or in connection with the instruction execution system, apparatus, or device. The medium can be an electronic, magnetic, optical, electromagnetic, infrared, or a semiconductor system (or apparatus or device). Examples of a computer-readable medium include a semiconductor or solid state memory, magnetic tape, a removable computer diskette, a random access memory (RAM), a read-only memory (ROM), a rigid magnetic disk and an optical disk. Current examples of optical disks include compact disk – read only memory (CD-ROM), compact disk – read/write (CD-R/W) and DVD. The computer-readable medium is a tangible, non-transitory item.

[0065] The computer program product may be a product having program instructions (or program code) to implement one or more of the described functions. Those instructions or code may be stored in a non-transitory computer readable storage medium in a data processing system after being downloaded over a network from a remote data processing system. Or, those instructions or code may be stored in a computer readable storage medium in a server data processing system and adapted to be downloaded over a network to a remote data processing system for use in a computer readable storage medium within the remote system.

[0066] In a representative embodiment, the interfaces and utility are implemented in a special purpose computing platform, preferably in software executed by one or more processors. The software is maintained in one or more data stores or memories associated with the one or more processors, and the software may be implemented as one or more computer programs. Collectively, this special-purpose hardware and software comprises the functionality described above.

[0067] While the above describes a particular order of operations performed by certain embodiments of the invention, it should be understood that such order is exemplary, as alternative embodiments may perform the operations in a different order, combine certain operations, overlap certain operations, or the like. References in the specification to a given embodiment indicate that the embodiment described may include a particular feature, structure, or characteristic, but every embodiment may not necessarily include the particular feature, structure, or characteristic.

[0068] Finally, while given components of the system have been described separately, one of ordinary skill will appreciate that some of the functions may be combined or shared in given instructions, program sequences, code portions, and the like.

[0069] The appliance is not limited to any particular type. The above-described operation may likewise be used in association with any known technique or mechanism that itself is used to intercept, decrypt, inspect, modify, rewrite and re-encrypt data from any machine, irrespective of the machine's physical configuration.

[0070] The techniques herein generally provide for the above-described improvements to a technology or technical field, as well as the specific technological improvements to network-connected secure appliances, such as described above.

[0071] The notion of providing a TLS inspector without a session cache (the "cacheless" nature of the technique) does not necessarily require that the TLS inspector be configured physically without such a cache, although that will be the usual configuration. A TLS inspector that has a session cache that is not utilized or otherwise bypassed is within the scope of the disclosed subject matter, which is claimed below. Thus, as used herein "cacheless" means that a session cache either is omitted or, if present, not utilized.

CLAIMS

1. A method operative within an intermediary positioned between a Transport Layer Security (TLS) client and a TLS server and that provides a TLS inspection function during a TLS session, comprising:
 - upon receipt from the TLS server of an original session ticket, generating a new session ticket;
 - applying an encryption function to the new session ticket;
 - outputting to the TLS client the encrypted new session ticket;
 - upon receipt from the TLS client of the encrypted new session ticket, decrypting the encrypted new session ticket to recover the original session ticket and the session context information; and
 - using the recovered original session ticket and the session context information to resume the TLS session.
2. The method as described in claim 1 wherein the new session ticket is generated by applying a transform function to the original session ticket and session context information associated with the TLS session.
3. The method as described in claim 2 wherein the transform function concatenates the original session ticket and the session context information.
4. The method as described in any of the preceding claims, wherein the encrypted new session ticket is received from the TLS client in a Client Hello.
5. The method as described in claim 4 wherein the TLS session is resumed at least in part by replacing the encrypted new session ticket in the Client Hello with the original session ticket, and forwarding the Client Hello to the TLS server.
6. The method as described in any of the preceding claims, wherein using the session context information includes obtaining a session key.
7. The method as described in claim 6 further including using the session key to decrypt a payload of the original session ticket.
8. The method as described in any of the preceding claims, wherein the new session ticket is generated and the encrypted new session ticket output in lieu of caching the original session ticket in a session cache.
9. An apparatus, comprising:
 - a processor;
 - computer memory holding computer program instructions executed by the processor, the computer program instructions comprising program code configured:

upon receipt from the TLS server of an original session ticket, to generate a new session ticket;
to apply an encryption function to the new session ticket;
to output to the TLS client the encrypted new session ticket;
upon receipt from the TLS client of the encrypted new session ticket, to decrypt the encrypted new session ticket to recover the original session ticket and the session context information; and
to use the recovered original session ticket and the session context information to resume the TLS session.

10. The apparatus as described in claim 9 wherein the new session ticket is generated by applying a transform function to the original session ticket and session context information associated with the TLS session.

11. The apparatus as described in claim 10 wherein the transform function concatenates the original session ticket and the session context information.

12. The apparatus as described in any of claims 9 to 11, wherein the encrypted new session ticket is received from the TLS client in a Client Hello.

13. The apparatus as described in claim 12 wherein the TLS session is resumed at least in part by replacing the encrypted new session ticket in the Client Hello with the original session ticket, and forwarding the Client Hello to the TLS server.

14. The apparatus as described in any of claims 9 to 13, wherein using the session context information includes obtaining a session key.

15. The apparatus as described in claim 14 further including using the session key to decrypt a payload of the original session ticket.

16. The apparatus as described in any of claims 9 to 15, wherein the new session ticket is generated and the encrypted new session ticket output in lieu of caching the original session ticket in a session cache.

17. A computer program product for a Transport Layer Security (TLS) inspection function during a TLS session, the computer program product comprising:

a computer readable storage medium readable by a processing circuit and storing instructions for execution by the processing circuit for performing a method according to any of claims 1 to 8.

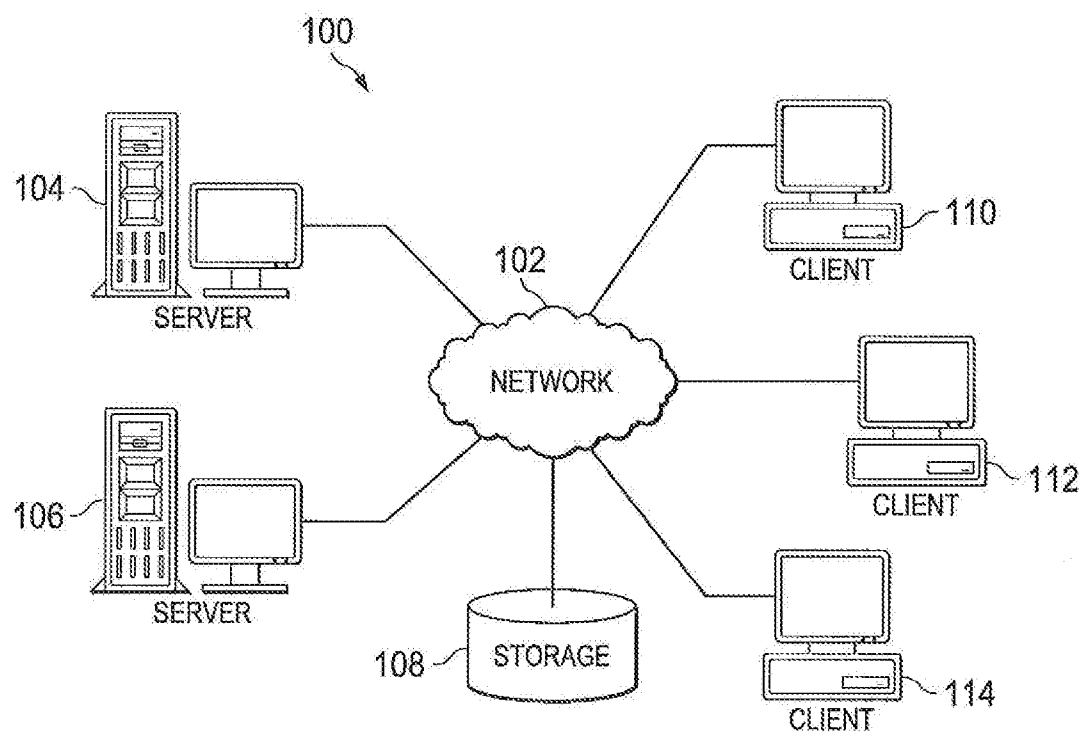
18. A computer program stored on a computer readable medium and loadable into the internal memory of a digital computer, comprising software code portions, when said program is run on a computer, for performing the method of any of claims 1 to 8.

19. An apparatus positioned between a Transport Layer Security (TLS) client and a TLS server, comprising:
a hardware processor, and

computer memory holding computer program instructions configured as a cacheless TLS inspector mechanism to:

receive a session ticket from the TLS server and, in response: (a) generate a composite session ticket, and (b) output to the TLS client the composited session ticket in lieu of caching the session ticket, and

receive the composited session ticket from the TLS client and, in response: (c) recover the session ticket, and (d) use the recovered session ticket to resume a session with the TLS server.



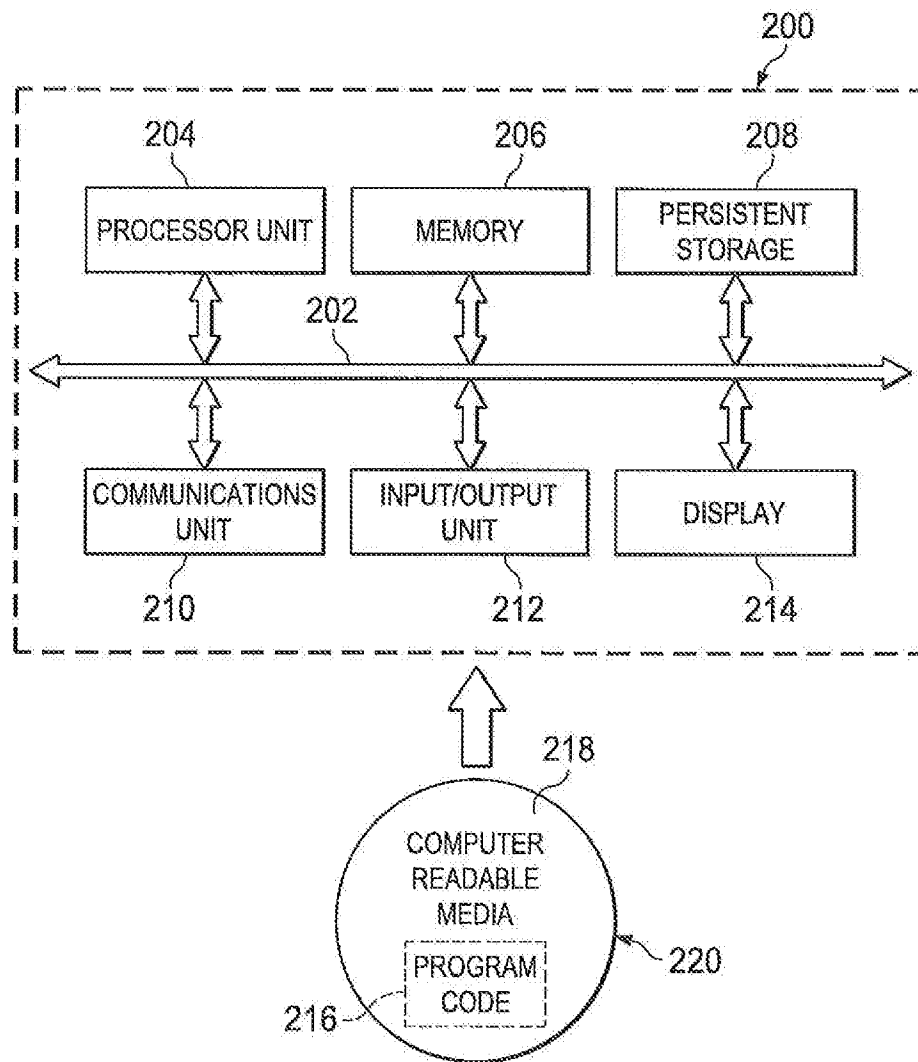


FIG. 2

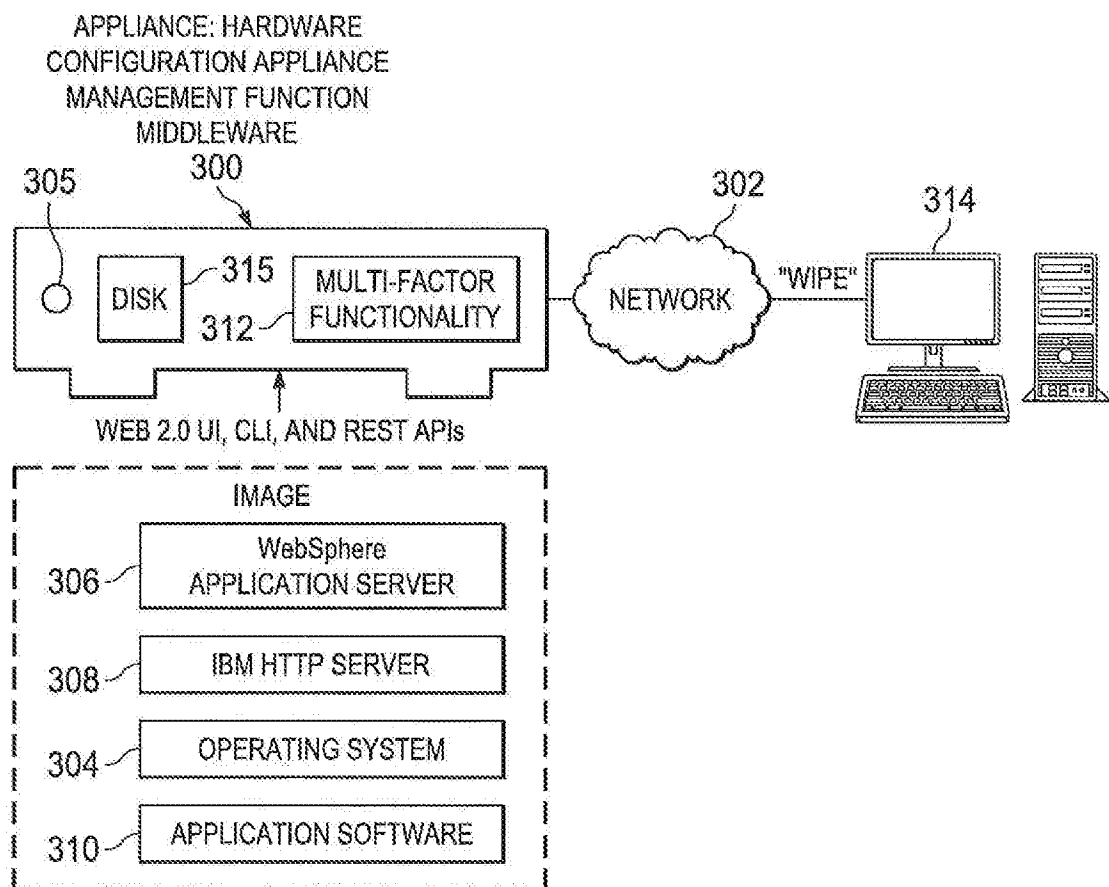


FIG. 3

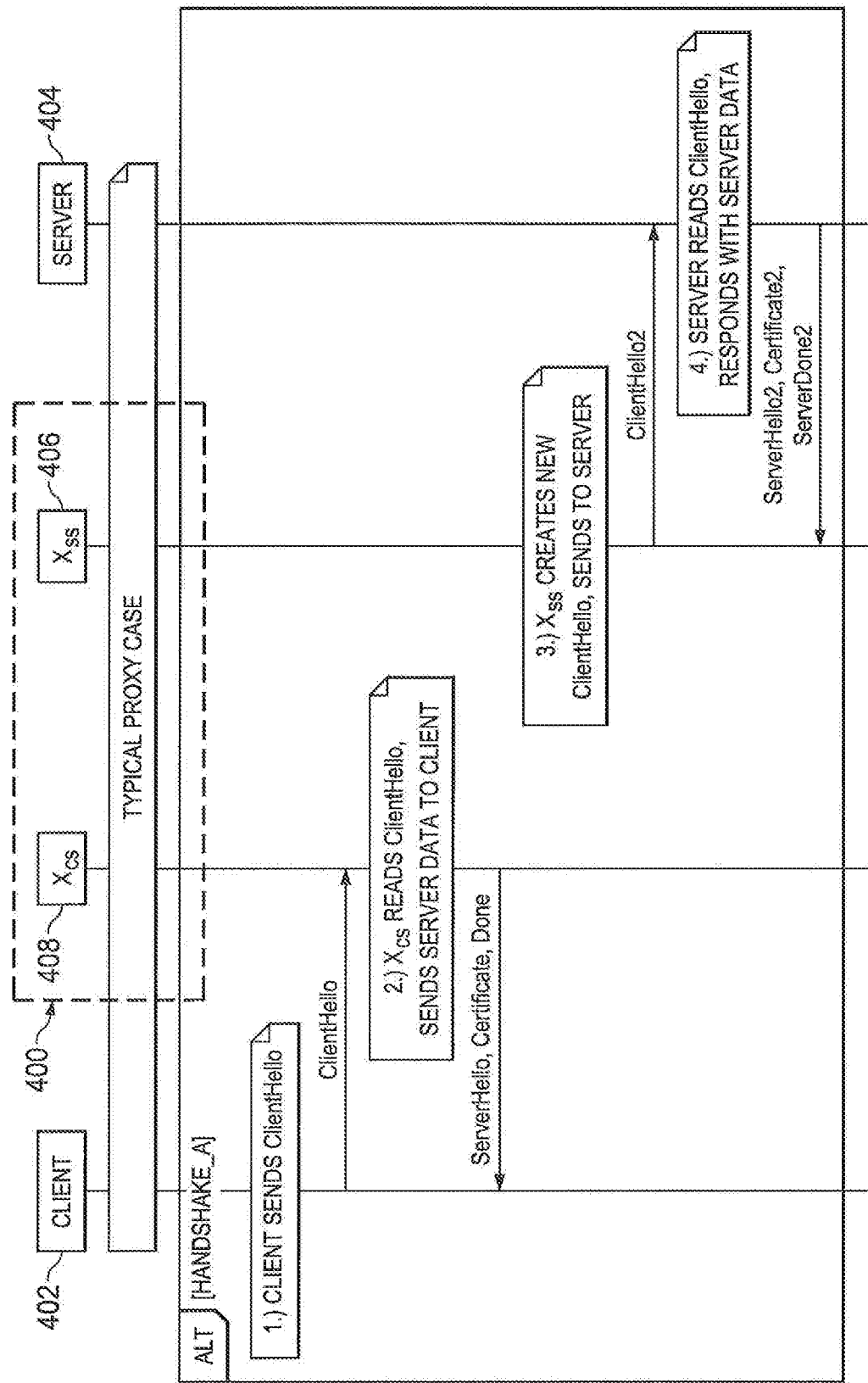


FIG. 4

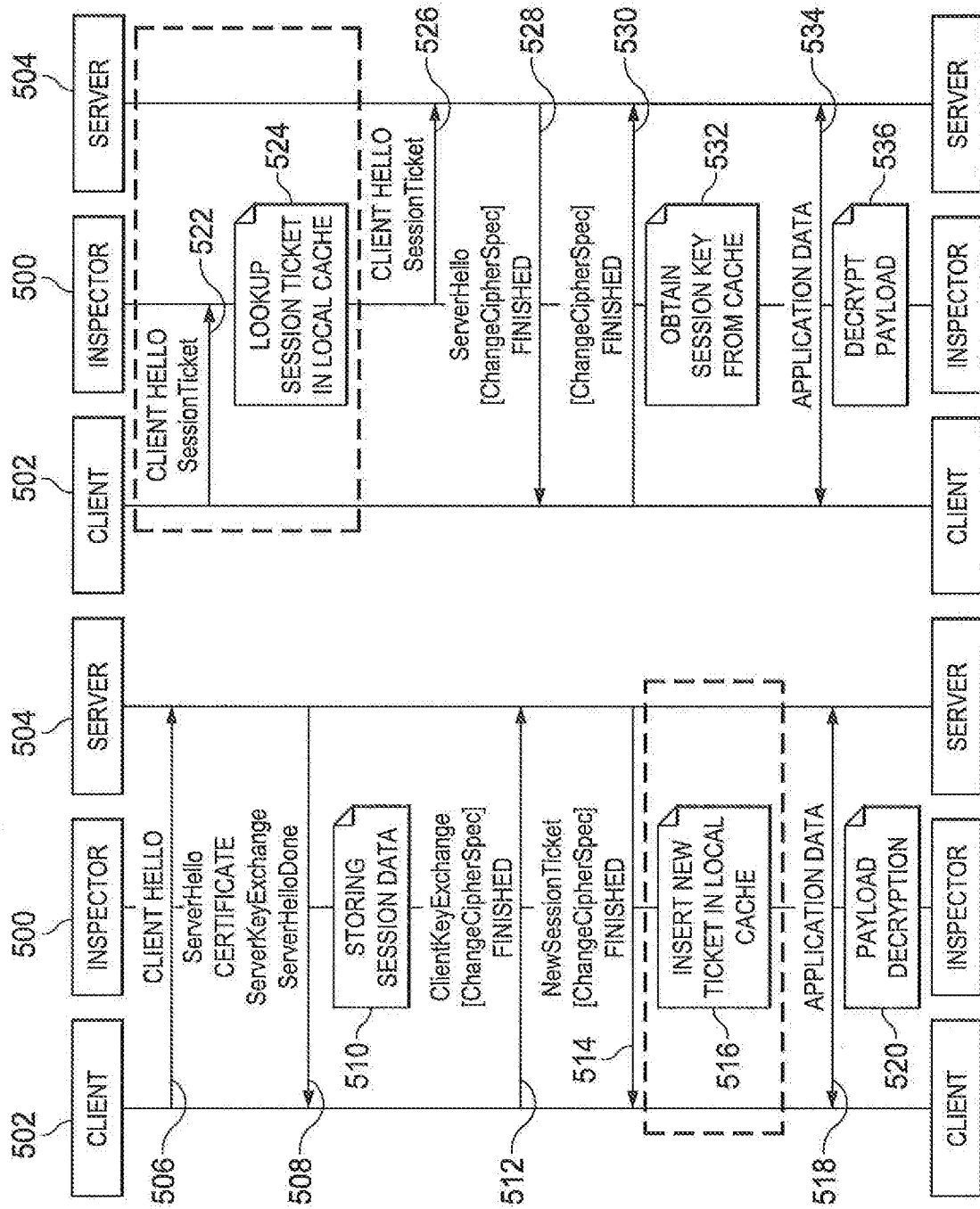


FIG. 5

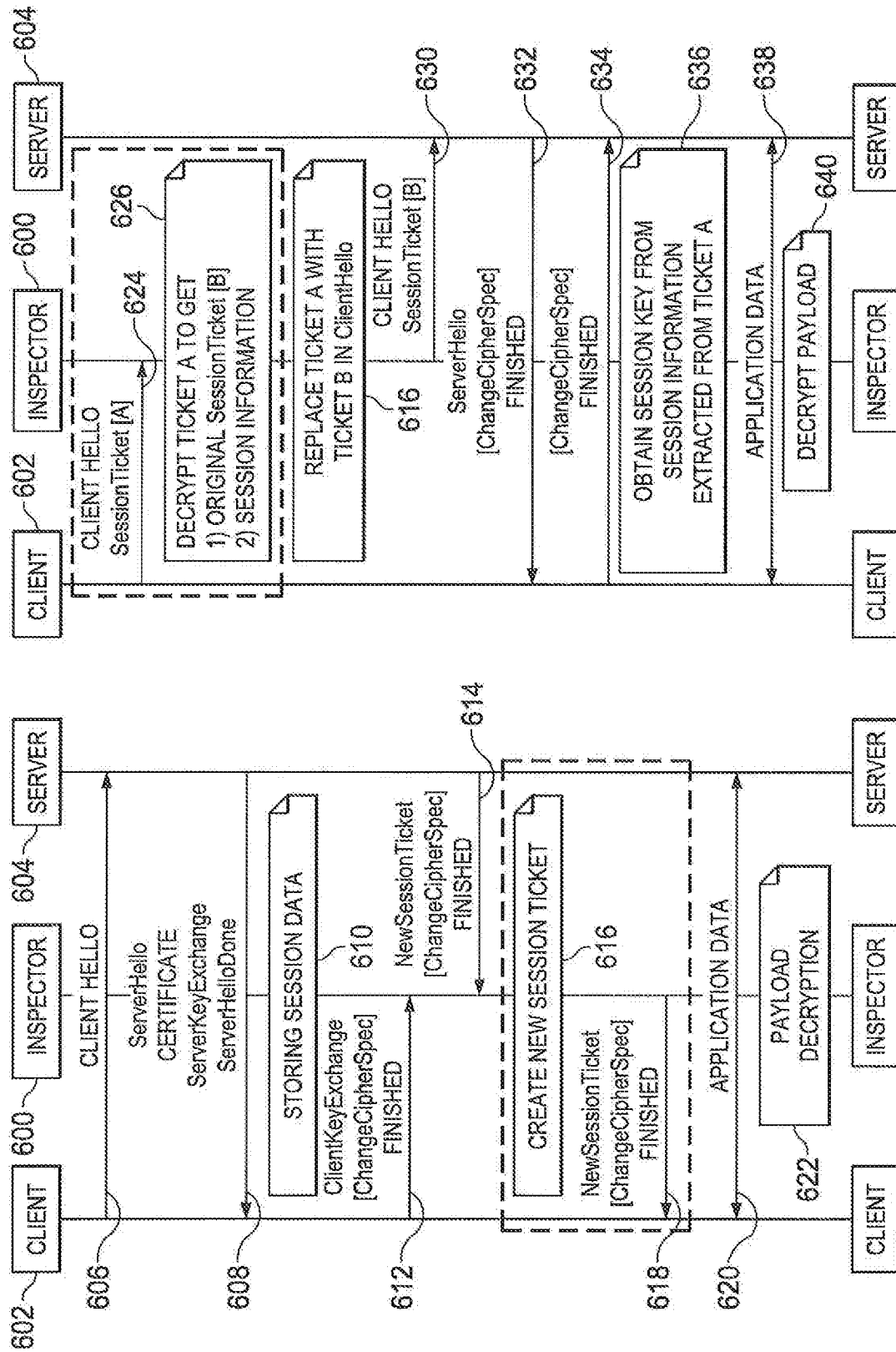


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB2018/053877

A. CLASSIFICATION OF SUBJECT MATTER

H04L 29/06(2006.01)i; H04L 29/08(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNABS, CNTXT, CNKI, DWPI, SIPOABS: TLS, transport layer security, server, client, session, ticket, encrypt, decrypt, context, hello

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2016315913 A1 (CISCO TECH INC) 27 October 2016 (2016-10-27) Description, paragraphs [0015], [0025]-[0033], [0043], Figures 1, 4, 5	1-19
A	US 2016048685 A1 (INT BUSINESS MACHINES CORP) 18 February 2016 (2016-02-18) The whole document	1-19
A	WO 2013112816 A1 (MCAFEE INC) 01 August 2013 (2013-08-01) The whole document	1-19

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

“A” document defining the general state of the art which is not considered to be of particular relevance

“E” earlier application or patent but published on or after the international filing date

“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

“O” document referring to an oral disclosure, use, exhibition or other means

“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search

25 September 2018

Date of mailing of the international search report

29 September 2018

Name and mailing address of the ISA/CN

STATE INTELLECTUAL PROPERTY OFFICE OF THE
P.R.CHINA
6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing
100088
China

Facsimile No. (86-10)62019451

Authorized officer

ZHENG,Jiaqing

Telephone No. 86-(010)-62411684

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/IB2018/053877

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
US	2016315913	A1	27 October 2016	WO	2016172035	A1	27 October 2016
				EP	3286896	A1	28 February 2018
				US	9608963	B2	28 March 2017
				CN	107534665	A	02 January 2018
US	2016048685	A1	18 February 2016	None			
WO	2013112816	A1	01 August 2013	CN	104067595	B	27 June 2017
				EP	2807813	A1	03 December 2014
				EP	2807813	A4	06 April 2016
				US	9026784	B2	05 May 2015
				US	2013198509	A1	01 August 2013
				CN	104067595	A	24 September 2014