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(54) **SYSTEM AND METHOD FOR AN ADAPTIVE TCP SYN COOKIE WITH TIME VALIDATION**

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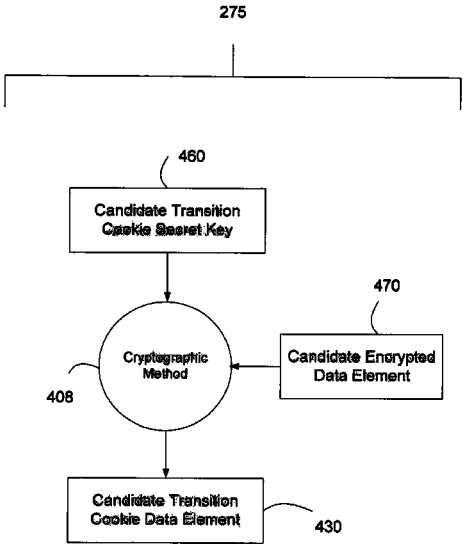
(57) **ABSTRACT**

Provided is a method and system for TCP SYN cookie validation. The method includes receiving a session SYN packet by a TCP session setup module of a host server, generating a transition cookie including a time value representing the actual time, sending a session SYN/ACK packet, including the transition cookie, in response to the received session SYN packet, receiving a session ACK packet, and determining whether a candidate transition cookie in the received session ACK packet comprises a time value representing a time within a predetermined time interval from the time the session ACK packet is received.

18 Claims, 10 Drawing Sheets



(58) **Field of Classification Search**
USPC 370/230.1; 709/227, 228; 726/22, 3, 6
See application file for complete search history.

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JP	2014143686		8/2014
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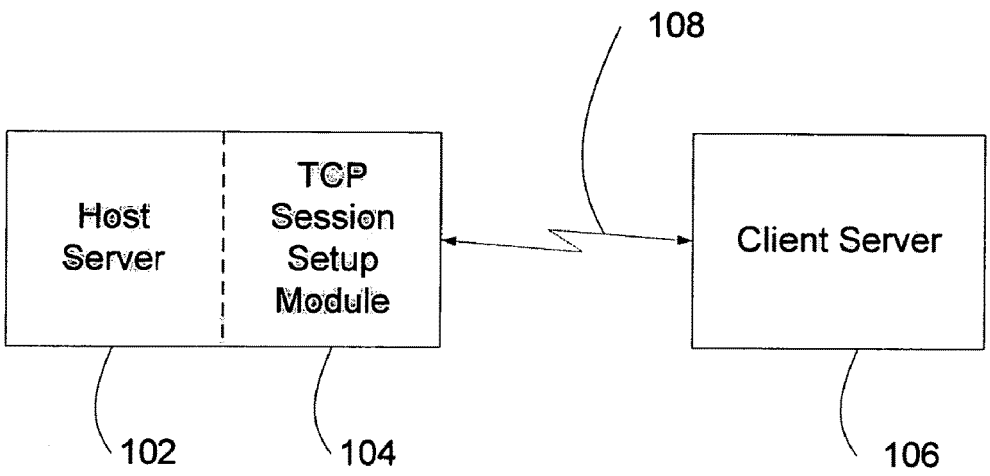
108
Host Server
TCP Session Setup Module
Client Server
102
104
106

Figure 1

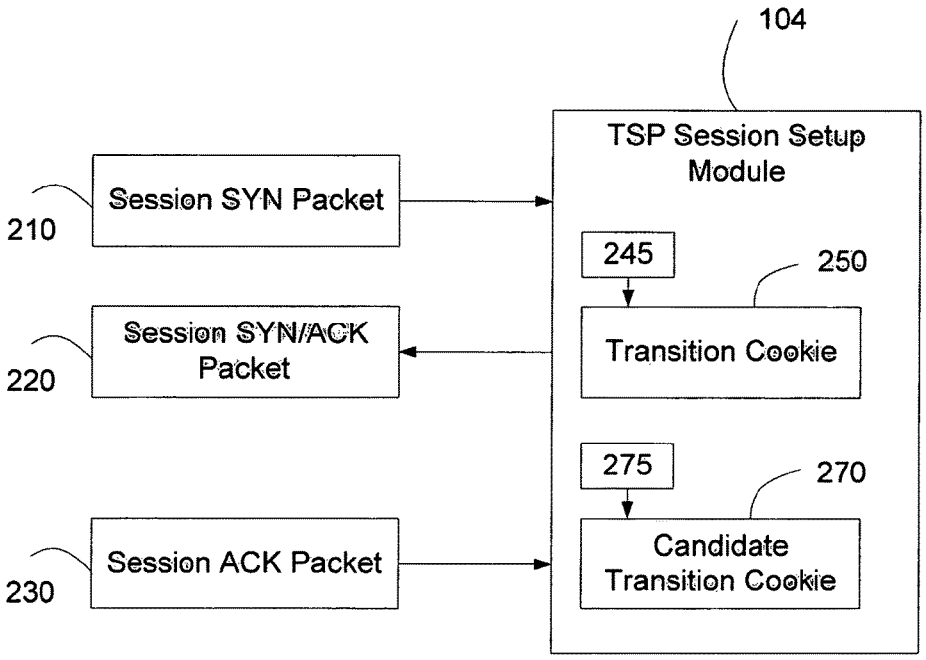
104
TSP Session Setup Module
Session SYN Packet
210
245
250
Session SYN/ACK Packet
220
Transition Cookie
275
270
Session ACK Packet
230
Candidate Transition Cookie

Figure 2

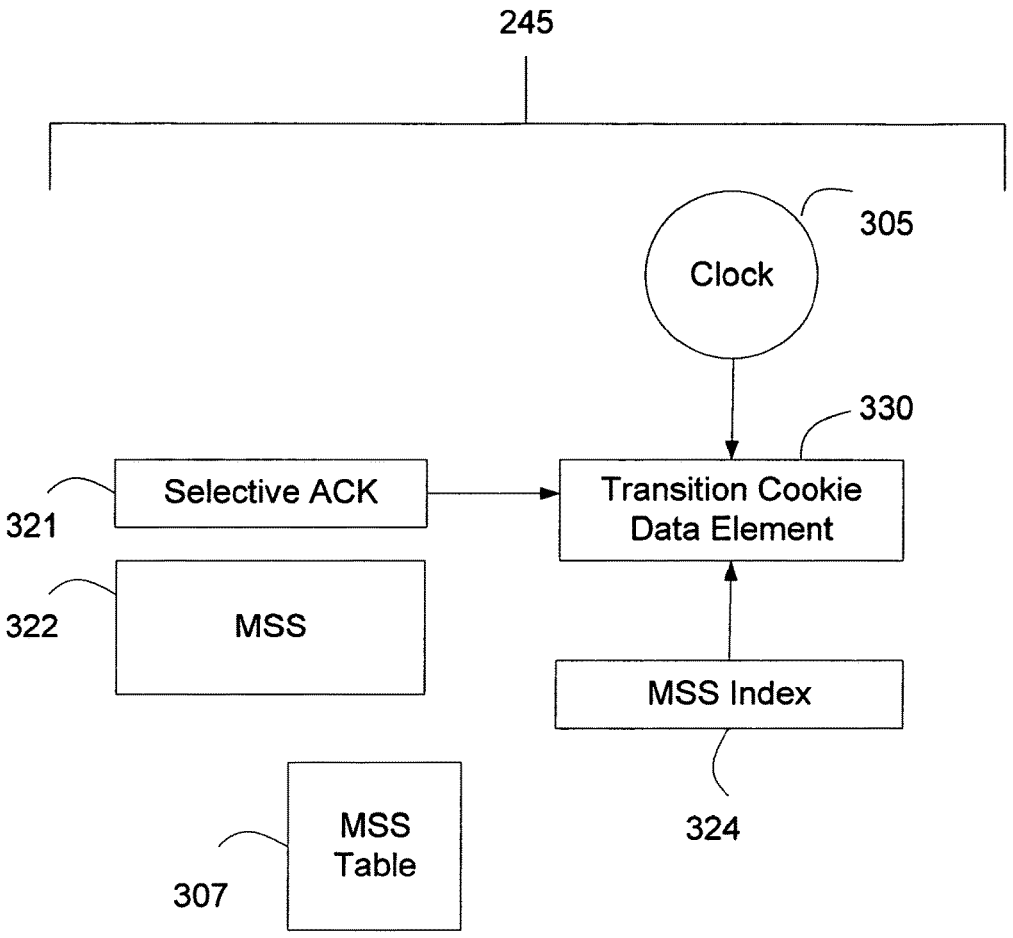
245
Clock
305
330
Selective ACK
321
Transition Cookie Data Element
MSS
322
MSS Index
324
MSS Table
307

Figure 3a

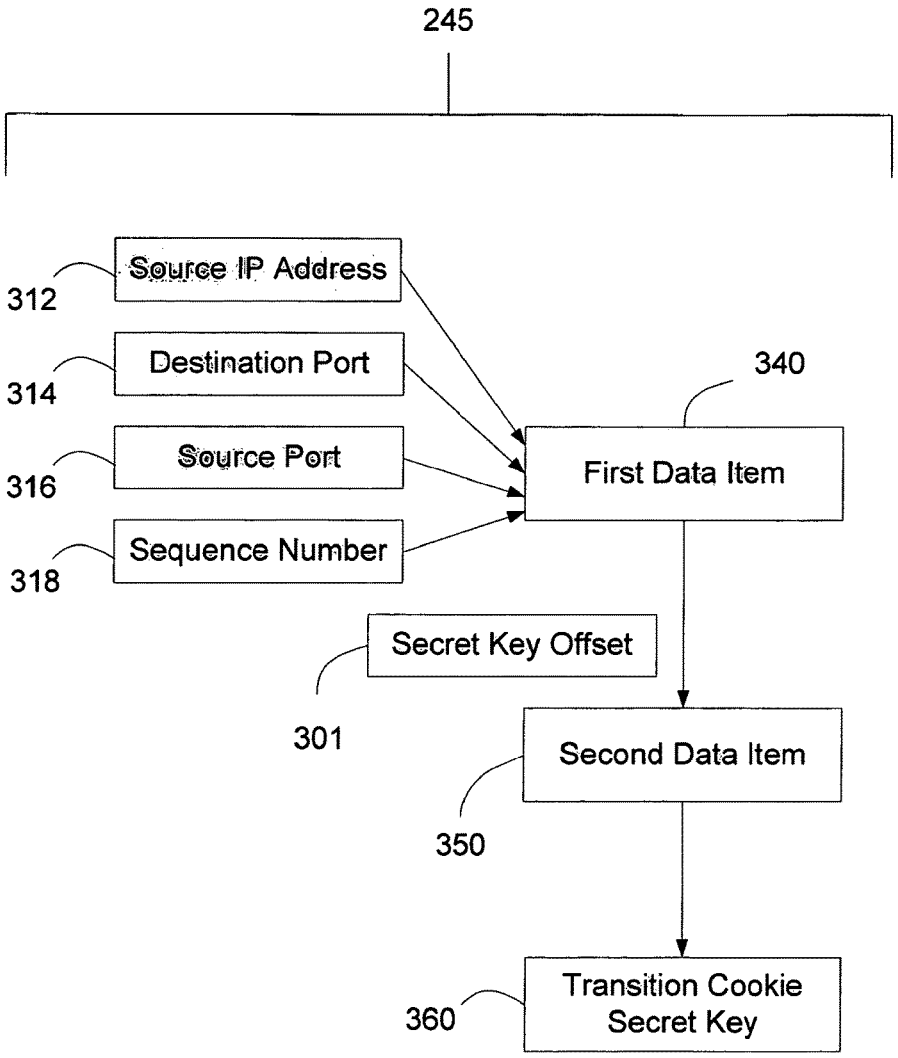
245
Source IP Address
312
Destination Port
314
Source Port
316
Sequence Number
318
340
First Data Item
Secret Key Offset
301
Second Data Item
350
Transition Cookie Secret Key
360

Figure 3b

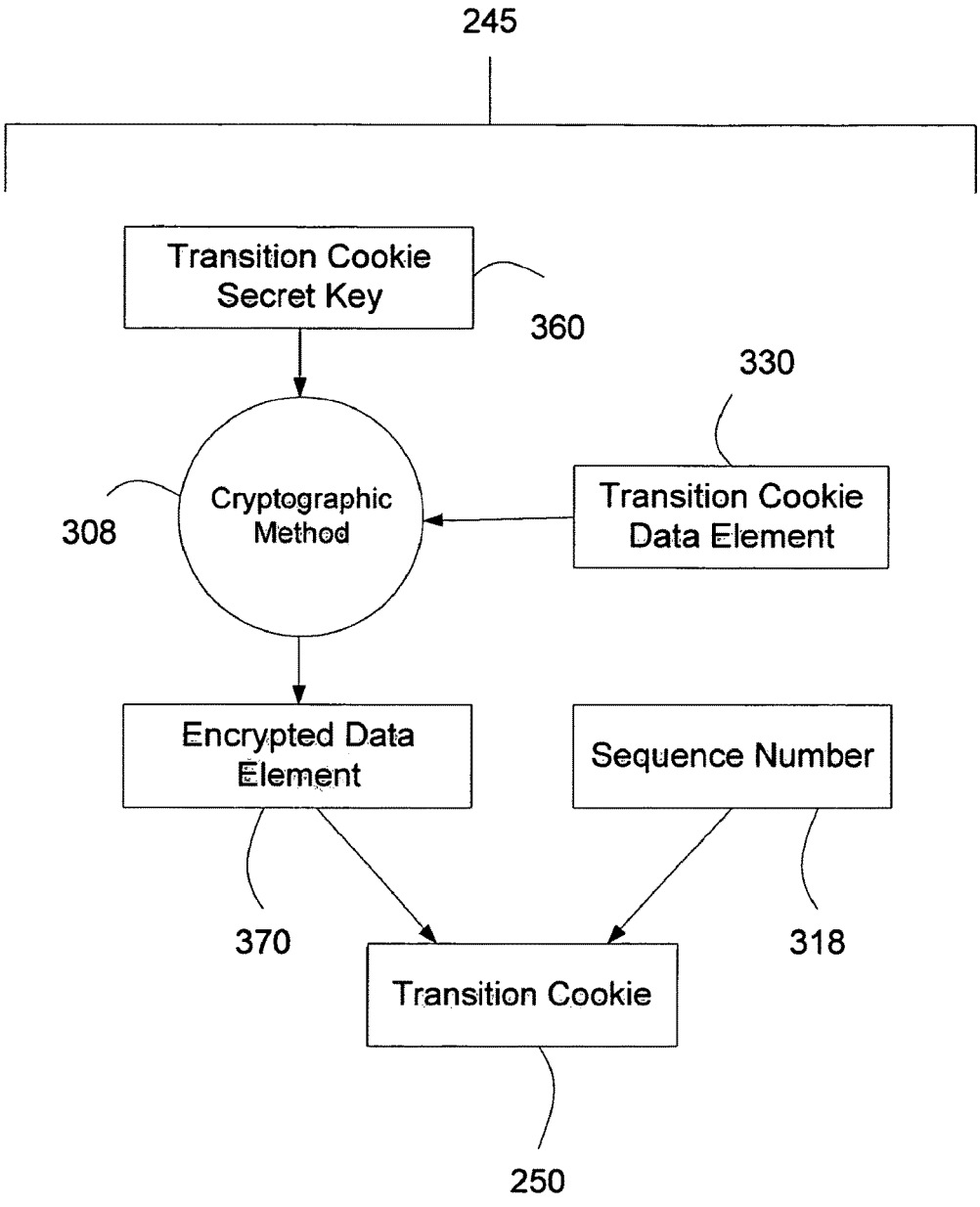
245
Transition Cookie Secret Key
360
330
Cryptographic Method
308
Transition Cookie Data Element
Encrypted Data Element
Sequence Number
370
318
Transition Cookie
250

Figure 3c

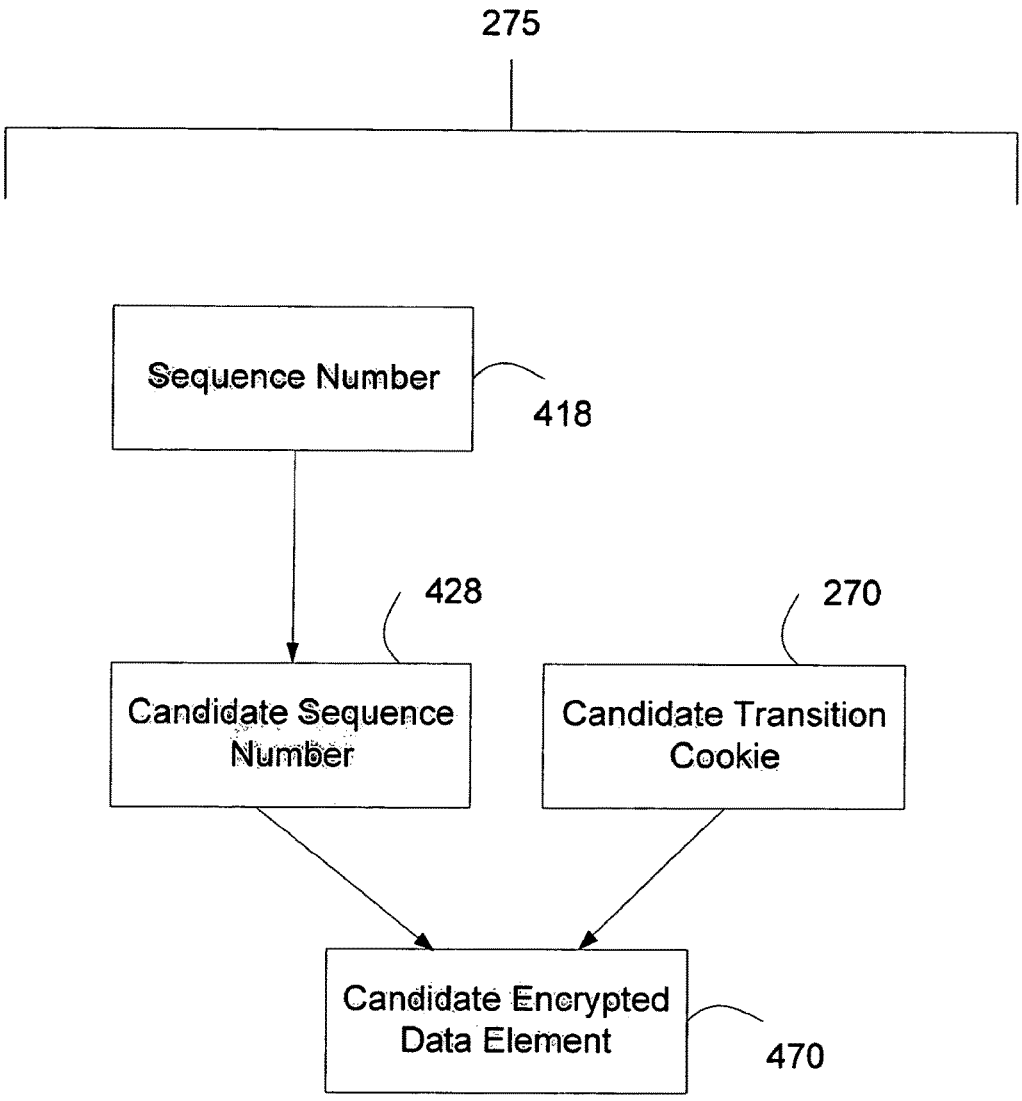
275
Sequence Number
418
428
270
Candidate Sequence Number
Candidate Transition Cookie
Candidate Encrypted Data Element
470

Figure 4a

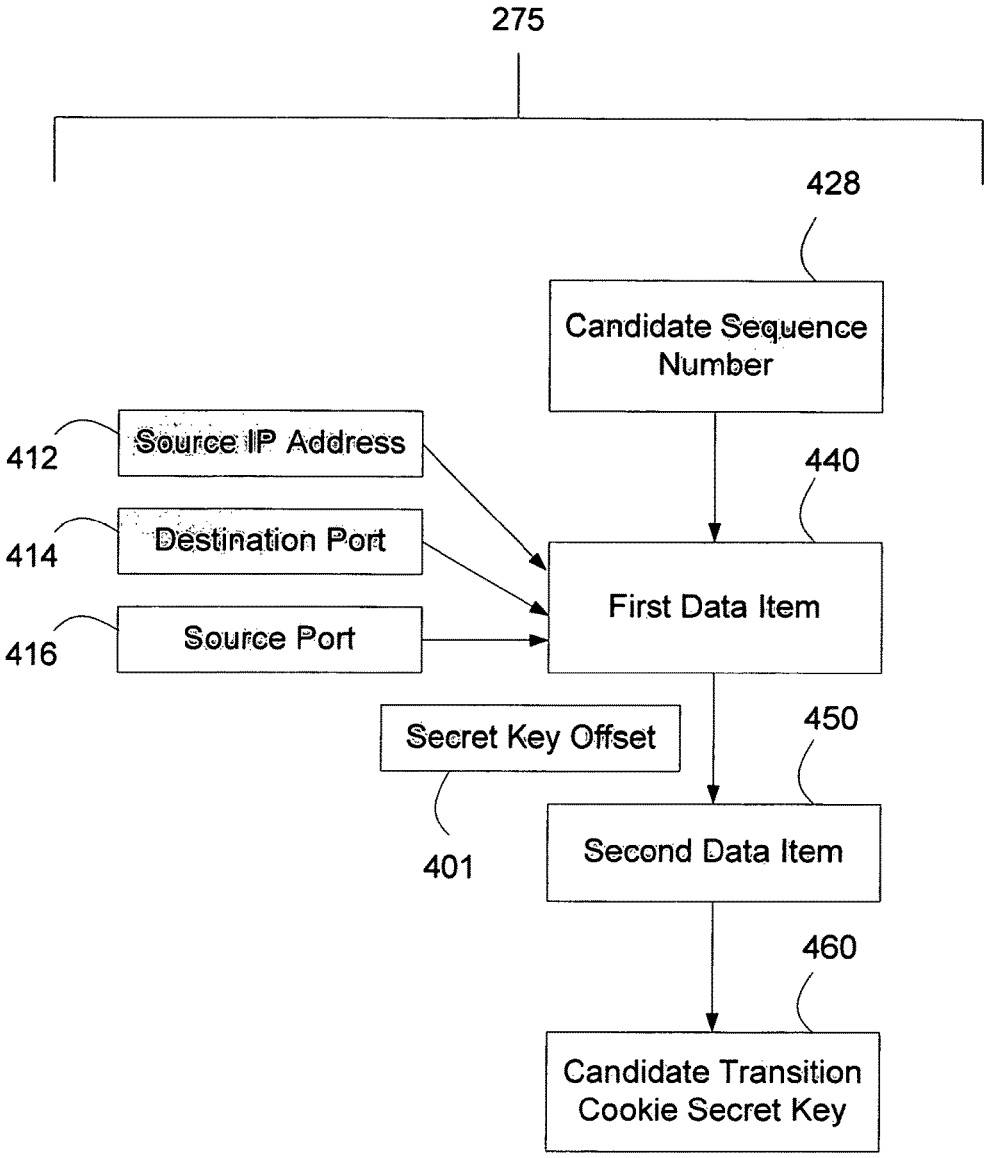
275
428
Candidate Sequence Number
412
Source IP Address
440
414
Destination Port
First Data Item
416
Source Port
Secret Key Offset
450
401
Second Data Item
460
Candidate Transition Cookie Secret Key

Figure 4b

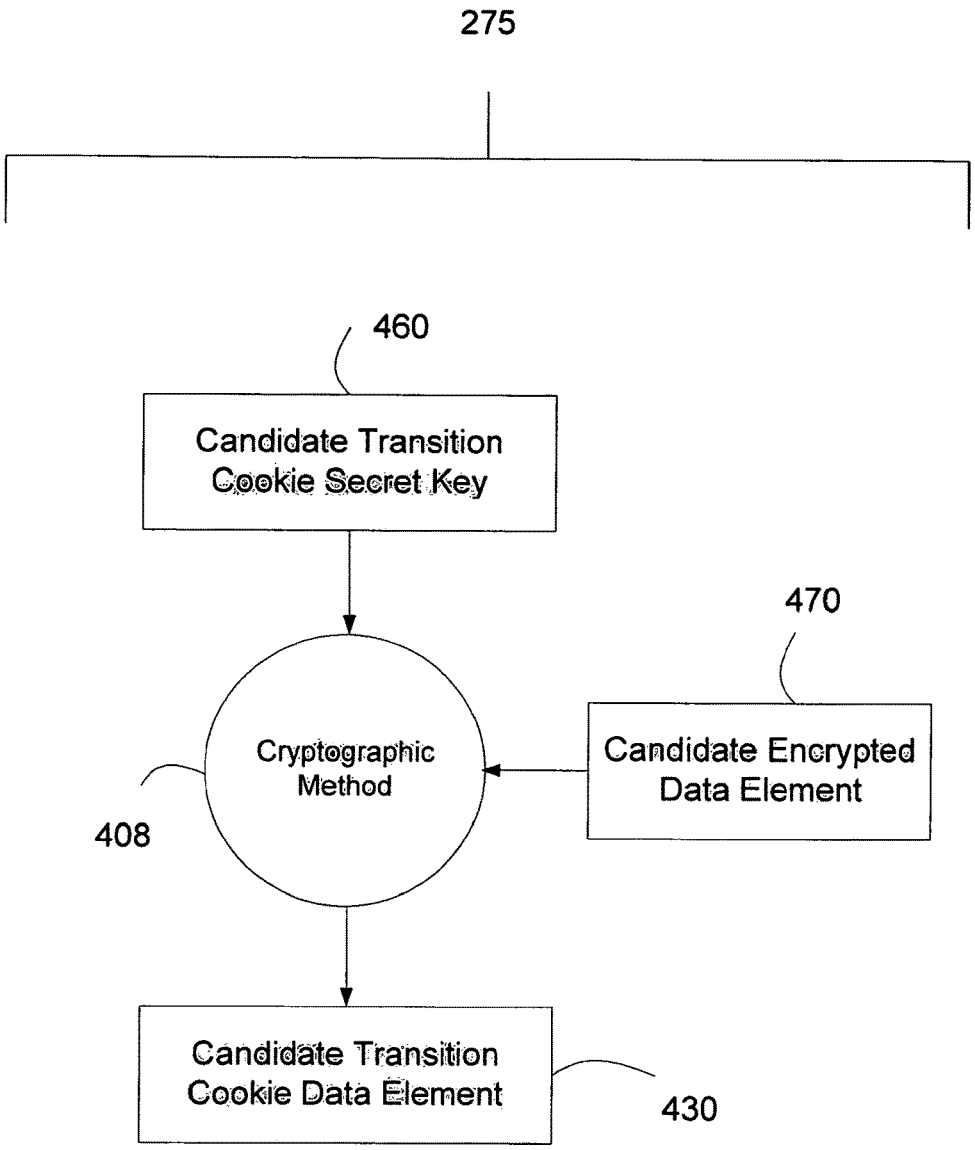
275
460
Candidate Transition Cookie Secret Key
470
Cryptographic Method
Candidate Encrypted Data Element
408
Candidate Transition Cookie Data Element
430

Figure 4c

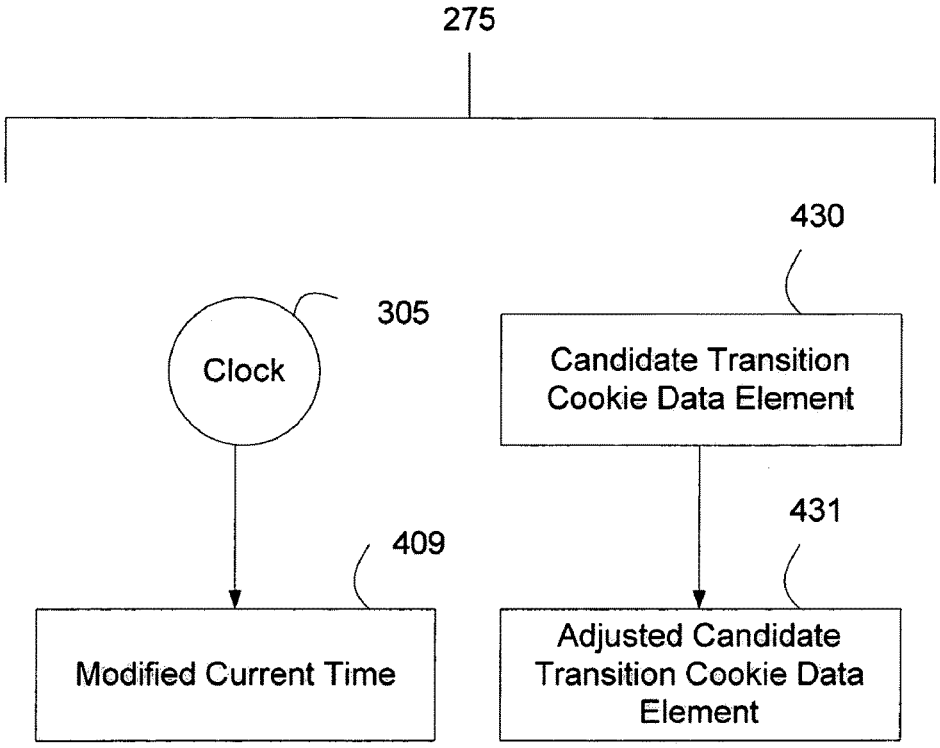
275
430
305
Clock
Candidate Transition Cookie Data Element
431
409
Modified Current Time
Adjusted Candidate Transition Cookie Data Element

Figure 4d

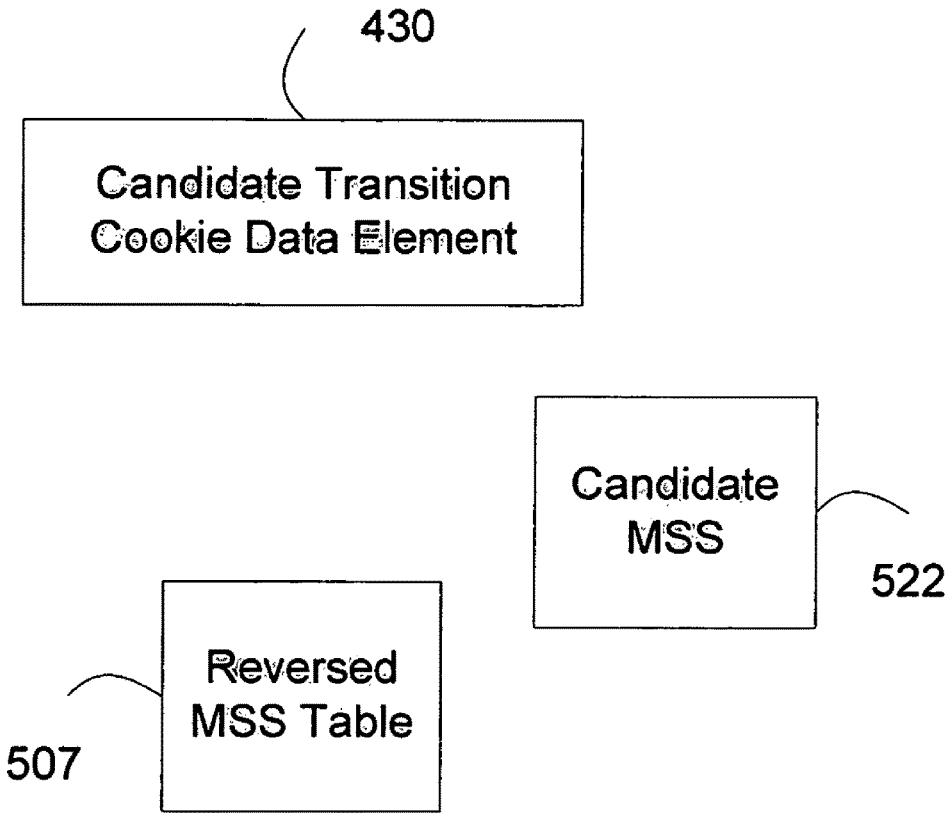
430
Candidate Transition Cookie Data Element
Candidate MSS
522
Reversed MSS Table
507

Figure 5

SYSTEM AND METHOD FOR AN ADAPTIVE TCP SYN COOKIE WITH TIME VALIDATION

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue; a claim printed with strikethrough indicates that the claim was canceled, disclaimed, or held invalid by a prior post-patent action or proceeding.

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation reissue application of U.S. Pat. No. 7,675,854 and claims benefit under 35 U.S.C. 120 as a continuation of application Ser. No. 13/413,191 filed on Mar. 6, 2012, which is an application for reissue of U.S. Pat. No. 7,675,854, originally issued on Mar. 9, 2010.

BACKGROUND OF THE INVENTION

When a TCP (Transmission Control Protocol) connection starts, a destination host receives a SYN (synchronize/start) packet from a source host and sends back a SYN ACK (synchronize acknowledge). The destination host normally then waits to receiver an ACK (acknowledge) of the SYN ACK before the connection is established. This is referred to as the TCP "three-way handshake."

While waiting for the ACK to the SYN ACK, a connection queue of finite size on the destination host keeps track of connections waiting to be completed. This queue typically empties quickly since the ACK is expected to arrive a few milliseconds after the SYN ACK is sent.

A TCP SYN flood attack is a well known denial of service attack that exploits the TCP three-way handshake design by having an attacking source host generate TCP SYN packets with random source addresses toward a victim host. The victim destination host sends a SYN ACK back to the random source address and adds an entry to the connection queue, or otherwise allocates server resources. Since the SYN ACK is destined for an incorrect or non-existent host, the last part of the "three-way handshake" is never completed and the entry remains in the connection queue until a timer expires, typically, for example, for about one minute. By generating phony TCP SYN packets from random IP addresses at a rapid rate, it is possible to fill up the connection queue and deny TCP services (such as e-mail, file transfer, or WWW) to legitimate users. In most instances, there is no easy way to trace the originator of the attack because the IP address of the source is forged. The external manifestations of the problem may include inability to get e-mail, inability to accept connections to WWW or FTP services, or a large number of TCP connections on your host in the state SYN_RCVD.

A malicious client sending high volume of TCP SYN packets without sending the subsequent ACK packets can deplete server resources and severely impact the server's ability to serve its legitimate clients.

Newer operating systems or platforms implement various solutions to minimize the impact of TCP SYN flood attacks. The solutions include better resource management, and the use of a "SYN cookie".

In an exemplary solution, instead of allocating server resource at the time of receiving a TCP SYN packet, the server sends back a SYN/ACK packet with a specially constructed sequence number known as a SYN cookie. When the server then receives an ACK packet in response to the SYN/ACK packet, the server recovers a SYN cookie from the ACK packet, and validates the recovered SYN cookie before further allocating server resources.

The effectiveness of a solution using a SYN cookie depends on the method with which the SYN cookie is constructed. However, existing solutions using a SYN cookie typically employ a hash function to construct the SYN cookie, which can lead to a high percentage of false validations of the SYN cookie, resulting in less than satisfactory protection again TCP SYN flood attack.

Therefore, there is a need for a better system and method for constructing and validating SYN cookies.

SUMMARY OF THE INVENTION

An aspect of the present invention provides a system for TCP SYN cookie validation. The system includes a host server including a processor and memory. The processor is configured for receiving a session SYN packet, generating a transition cookie, the transition cookie comprising a time value representing the actual time, sending a session SYN/ACK packet, including the transition cookie, in response to the received session SYN packet, receiving a session ACK packet, and determining whether a candidate transition cookie in the received session ACK packet comprises a time value representing a time within a predetermined time interval from the time the session ACK packet is received.

One aspect of the invention includes the system above in which the processor is further configured for regarding the received session ACK packet as valid if the candidate transition cookie in the received session ACK packet comprises a time value representing a time within a predetermined time interval from the time the session ACK packet is received.

In another aspect of the invention, the predetermined time interval is in the range of one to six seconds.

In one aspect of the invention, the predetermined time interval is three seconds.

In another aspect of the invention, the step of generating the transition cookie includes the use of data obtained from the session SYN packet.

In one aspect of the invention, the data obtained from the session SYN packet comprises the source IP address of an IP header associated with the session SYN packet.

In another aspect of the invention, the data obtained from the session SYN packet comprises the sequence number of a TCP header associated with the session SYN packet.

In another aspect of the invention, the data obtained from the session SYN packet comprises a source port associated with the session SYN packet.

In another aspect of the invention, the data obtained from the session SYN packet comprises a destination port associated with the session SYN packet.

Another aspect of the present invention provides a method for TCP SYN cookie validation. The method includes receiving a session SYN packet by a TCP session setup module, generating a transition cookie by the TCP session setup module, the transition cookie comprising a time value representing the actual time, sending a session SYN/ACK packet, including the transition cookie, in response to the received session SYN packet, receiving a session ACK packet, and determining whether a candidate transition cookie in the received session ACK packet comprises a time value representing a time within a predetermined time interval from the time the session ACK packet is received.

In an aspect of the invention, the method further includes indicating the received session ACK packet comprises a valid candidate transition cookie if the time value of the candidate transition cookie is within a predetermined time interval of the time the session ACK packet is received.

In another aspect of the invention, the step of generating the transition cookie includes the use of data obtained from the session SYN packet.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram illustrating a host server including a TCP session setup module and a client server, in accordance with an embodiment of the present invention;

FIG. **2** is a schematic diagram of a TCP/IP handshake in accordance with an embodiment of the present invention;

FIG. **3**a illustrates a method including steps for generating a transition cookie data element by a transition cookie generator **245**, in accordance with an embodiment of the present invention;

FIG. **3**b illustrates a method including steps for generating a transition cookie secret key by a transition cookie generator **245** based on data obtained from the received session SYN packet, in accordance with an embodiment of the present invention;

FIG. **3**c illustrates a method including steps for generating a transition cookie based on a transition cookie data element, a transition cookie secret key, and data obtained from a received session SYN packet in accordance with an embodiment of the present invention;

FIG. **4**a illustrates steps for generating a candidate encrypted data element by a transition cookie validator **275** based on data obtained from a received session ACK packet, in accordance with an embodiment of the present invention;

FIG. **4**b illustrates a method including steps for generating a candidate transition cookie secret key by a transition cookie validator **275** based on data obtained from a received session ACK packet and a candidate sequence number, in accordance with an embodiment of the present invention;

FIG. **4**c illustrates a method including steps for generating a candidate transition cookie data element by a transition cookie validator **275** based on a candidate encrypted data element and a candidate transition cookie secret key, in accordance with an embodiment of the present invention;

FIG. **4**d illustrates a method including the steps for validating a candidate transition cookie data element, in accordance with an embodiment of the present invention; and

FIG. **5** illustrates a method including steps for generating information based on a validated candidate transition cookie data element, in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION

In the following description, for purposes of explanation, specific numbers, materials and configurations are set forth in order to provide a thorough understanding of the invention. It will be apparent, however, to one having ordinary skill in the art, that the invention may be practiced without these specific details. In some instances, well-known features may be omitted or simplified so as not to obscure the present invention. Furthermore, reference in the specification to "one embodiment" or "an embodiment" means that a particular feature, structure or characteristic described in connection with the embodiment is included in at least one embodiment of the invention. The appearances of the phrase "in an embodiment" in various places in the specification are not necessarily all referring to the same embodiment.

Transmission Control Protocol ("TCP") is one of the main protocols in TCP/IP networks. Whereas the Internet Protocol ("IP") deals only with packets, TCP enables two hosts to establish a connection and exchange streams of data. TCP guarantees delivery of data and also guarantees that packets will be delivered in the same order in which they were sent.

The terms "host server" and "client server" referred to in the descriptions of various embodiments of the invention herein described are intended to generally describe a typical system arrangement in which the embodiments operate. The "host server" generally refers to any computer system interconnected to a TCP/IP network, including but not limited to the Internet, the computer system comprising at a minimum a processor, computer memory, and computer software. The computer system is configured to allow the host server to participate in TCP protocol communications over its connected TCP/IP network. Although the "host server" may be a single personal computer having its own IP address and in communication with the TCP/IP network, it may also be a multi-processor server or server bank. The "client server" is similar to the "host server", although it is understood that the "client server" may, in fact, be a single personal computer attached to the TCP/IP network. The only difference between the client and the host server for the purposes of the present invention is that the host server receives the SYN from the client server, sends a SYN ACK to the client server, and waits for the ACK from the client server.

FIG. **1** is a schematic diagram illustrating an embodiment of the present invention. A host server **102** may include a TCP session module **104**. The TCP session setup module **104** can engage in a TCP handshake **108**, such as described above, with a client server **106**. In an embodiment, the TCP session setup module **104** is a software component of the host server **102**. In one embodiment, the TCP session setup module **104** is implemented in an Application Specific Integrated Circuit ("ASIC") or a Field Programmable Gate Array ("FPGA"). It is the TCP session setup module that handles the "3-way handshake" **108** between the host server **102** and the client server **106**. The TCP session setup module may itself also incorporate modules for sending and receiving TCP session packets. These modules may include but are not limited to a session SYN packet receiver, a session SYN/ACK packet sender, and a session ACK packet receiver, which are all known to those of ordinary skill in the computer arts.

The TCP sessions setup module **104** may itself be embedded in one or more other host server modules (not shown). The TCP session setup module may alternatively comprise a hardware or firmware component. For example, the software which handles the TCP handshake **108** on behalf of the host server **102** may be programmed onto a externally programmable read-only memory ("EPROM") (not shown), and the EPROM may then be integrated into the host server. In another example, the ASIC or FPGA is integrated into the host server.

FIG. **2** illustrates a TCP session setup module **104** processing TCP/IP segments (not shown), such as session SYN packet **210**, session SYN/ACK packet **220**, and session ACK packet **230**.

A TCP/IP segment includes a TCP header and an IP header as described in IETF RFC 793 "Transmission Control Protocol" section 3.1 "Header Format", incorporated herein by reference. A TCP header optionally includes a sack-permitted option as described in IETF RFC 2018 "TCP Selective Acknowledgement Options" section 2 "Sack-Per-

mitted Option", incorporated herein by reference. A session SYN packet **210** is a TCP/IP segment with the SYN control bit in the TCP Header set to "1". A session SYN/ACK packet **220** is a TCP/IP segment with the SYN control bit and the ACK control bit in the TCP header set to "1". A Session ACK Packet **230** is a TCP/IP segment with the ACK control bit in the TCP header set to "1".

Referring to FIG. **2**, in an embodiment, the TCP session setup module **104** receives a session SYN packet **210**, obtains data from a session SYN packet **210**, such as but not limited to the source IP address of the IP header, or the sequence number of the TCP header, and uses the data to generate a transition cookie **250**. The transition cookie **250** is preferably a 32-bit data element. In response to the session SYN packet **210**, the TCP session setup module **104** creates and sends out a session SYN/ACK packet **220** in accordance with IETF RFC 793 "Transmission Control Protocol" section 3.4 "Establishing a connection", incorporated herein by reference. The TCP session setup module **104** preferably includes the transition cookie **250** as the sequence number of the TCP header in the session SYN/ACK packet **220**.

After the TCP session setup module **104** has sent out the session SYN/ACK packet **220**, it waits for receipt of a responding session ACK packet **230**. In an embodiment, when a session SYN/ACK packet **230** is received, the TCP session setup module **104** generates a 32-bit candidate transition cookie **270** such that the sum of candidate transition cookie **270** and a value of "1" equal the acknowledgement number of the TCP header in the session ACK packet **230**. For example, if the acknowledgement number is "41B4362A" in hexadecimal format the candidate transition cookie **270** is "41B43629" in hexadecimal format; the sum of "41B43629" and a value of "1" equals "41B4362A". In another example, if the acknowledgement number is "00A30000" in hexadecimal format the candidate transition cookie **270** is "00A2FFFF" in hexadecimal format; the sum of "00A2FFFF" and a value of "1" equals "00A30000". In another example, if the acknowledgement number is "00000000" in hexadecimal format the Candidate Transition Cookie **270** is "FFFFFFFF" in hexadecimal format; the sum of "FFFFFFFF" and a value of "1" equals "00000000", with the most significant bit carried beyond the 32-bit boundary. The TCP session setup module **104** may thus validate the candidate transition cookie **270** in this manner. If the TCP session setup module **104** determines that the candidate transition cookie **270** is thus valid, the session ACK packet **230** is also valid. In this case, the TCP session setup module **104** obtains data from the validated session ACK packet **230** and sends the data and information generated during the validation of candidate transition cookie **270** to a computing module (not shown) for further processing.

In order to generate and validate transition cookies **250**, **270**, the TCP session setup module **104** may include a transition cookie generator **245** and a transition cookie validator **275**, respectively. Alternatively, the generation and validation may be performed directly by the TCP session setup module **104**. In the descriptions herein, references to the TCP and transition cookie validator **275** are understood to include any of the alternative embodiments of these components.

A transition cookie generator **245** includes the functionality of generating a transition cookie based on the data obtained from a session SYN **210** packet received by the TCP session setup module **104**.

A transition cookie validator **275** includes the functionality of validating a candidate transition cookie **270** generated based on data obtained from a session ACK packet **230** received by the TCP session setup module **104**.

In exemplary operation, a transition cookie generator **245** is software or firmware that generates a transition cookie **250** based on data obtained from a session SYN packet **210** received by the TCP session setup module **104**. An exemplary method for generating a transition cookie **250** by a transition cookie generator **245** includes multiple steps as illustrated in FIGS. **3**a-**3**c.

FIG. **3**a illustrates exemplary steps for generating a transition cookie data element **330** by a transition cookie generator **245**. A transition cookie generator **245** includes a clock **305** indicating the current time of day in microseconds in a 32-bit format.

The transition cookie data element **330** is preferably a 32-bit data element, generated by the transition cookie generator **245** based on the selective ACK **321**, the MSS index **324** and the 32-bit current time of day indicated by clock **305**. Selective ACK **321** is a 1-bit data element which is set to a value of "1" by transition cookie generator **245** if a TCP header in a received session SYN packet **210** includes an optional sack-permitted option, or to "**0**" if a TCP header in a received session SYN packet **210** does not include an optional sack-permitted option.

Maximum Segment Size ("MSS") **322** is the maximum number of bytes that TCP will allow in an TCP/IP packet, such as session SYN packet **210**, session SYN/ACK packet **220**, and session ACK packet **230**, and is normally represented by an integer value in a TCP packet header. If a TCP header in a received session SYN packet **210** includes a maximum segment size option, the transition cookie generator **245** sets the MSS **322** to equal the maximum segment size option data of the maximum segment size option. Otherwise, if the TCP header in a received session SYN packet **210** does not include a maximum segment size option, the transition cookie generator **245** sets the MSS **322** to a default value, for example, such as integer "536". The MSS index **324** is a 4-bit data element set by the transition cookie generator **245** based on the MSS **322**. The transition cookie generator **245** preferably includes an MSS table **307**, which maps an MSS **322** to an MSS index **324**. The transition cookie generator **245** maps a MSS **322** with the MSS table **307** to set the value of MSS index **324**. For example, MSS **322** has an integer value of "1460". After the mapping, MSS index **324** has a value of "4" as represented in hexadecimal format. In an alternative embodiment, means other than an MSS table **307** may be employed to determine the MSS index **324** value, such as the use of a mapping algorithm.

In generating a transition cookie data element **330**, the transition cookie generator **245** sets a transition cookie data element **330** to equal the 32-bit current time of day indicated by clock **305**. For example, the 32-bit current time of day may be "A68079E8" as represented in hexadecimal format, so the transition cookie data element **330** has a value of "A68079E8".

Next, the transition cookie generator **245** replaces the least significant 4 bits (bit **0**-**3**) of transition cookie data element **330** with the MSS index **324**, and replaces bit **4** of a transition cookie data element **330** with selective ACK **321**. For example, if a transition cookie data element **330** has been set to a value of "A68079E8", selective ACK **321** has a value of "1", and MSS index **324** has a value of "4" as represented in hexadecimal format, after the replacements, transition cookie data element **330** has a value of "A68079F4" in hexadecimal format.

FIG. **3**b illustrates exemplary steps for generating a transition cookie secret key **360**, such as by a transition cookie generator **245** based on data obtained from a received session SYN packet **210**. The data used in generating the transition cookie secret key **360** may include at least the source IP address **312** of an IP header, a destination port **314**, a source port **316** and a sequence number **318** of a TCP header in a received session SYN packet **210**. In generating a transition cookie secret key **360**, a transition cookie generator **245** forms a 96-bit data element, a first data item **340**, by concatenating a source IP address **312**, a sequence number **318**, a source port **316**, and a destination port **314**. For example, if the source IP address **312** is 192.168.1.134, the hexadecimal representation being "C0A80186", the sequence number **318** is "9A275B84", the source port **316** is 4761, the hexadecimal representation being "1299", and the destination port **314** is 240, the hexadecimal representation being "00F0", then, after the concatenation, the first data item **340** has a hexadecimal value of "C0A801869A275B84129900F0".

Next, since the transition cookie secret key **360** is a 128-bit data element, the transition cookie generator **245** may use a hash function to generate the transition cookie secret key **360** from the first data item **340**. Further, the transition cookie generator **245** may use a secret key offset **301**, which may be a 6-bit integer value, to select a 6-bit non-negative integer from first data item **340** starting at the bit indicated by secret key offset **301**. For example, if the secret key offset **301** has a value of "12" and the first data item **340** has a hexadecimal value of "C0A801869A275B84129900F0", the transition cookie generator **245** selects a 6-bit non-negative integer from the first data item **340** starting at bit **12** (bit **12-17**). The selected non-negative integer is of this example is thus "16". The transition cookie generator **245** then uses the selected non-negative integer to select 64 bits of data from the first data item **340**, starting at the bit indicated by the selected non-negative integer, to generate the second data item **350**, which has 64 bits.

For example, if the selected non-negative integer is "8" and the first data item **340** has a hexadecimal value of "C0A801869A275B84129900F0", the transition cookie generator **245** selects 64 bits (bit **8-71**) of the first data item **340** to generate a second data item **350**, having a hexadecimal value of "869A275B84129900". In another example, if the selected non-negative integer is "52", and the transition cookie generator **245** selects 64 bits (bit **52-95** and bit **0-19**) of the first data item **340** in a wrap-around fashion, bits **52-95** have a hexadecimal value of "C0A801869A2", and bit **0-19** have a hexadecimal value of "900F0", so the generated second data item **350** has a hexadecimal value of "900F0C0A801869A2". The transition cookie generator **245** then generates a transition cookie secret key **360** by storing the second data item **350** in the least significant 64 bits (bit **0-63**) of the transition cookie secret key **360** and setting the most significant 64 bits (bit **64-127**) to "0". For example, if the second data item **350** has a hexadecimal value of "869A275B84129900", the transition cookie secret key **360** has a hexadecimal value of "0000000000000000869A275B84129900".

FIG. **3**c illustrates exemplary steps for generating a transition cookie **250** based on a transition cookie data element **330**, a transition cookie secret key **360**, and data obtained from a received session SYN packet **210**, including a sequence number **318** of a TCP header in a received session SYN packet **210**. To generate a transition cookie **250**, a transition cookie generator **245** applies a cryptographic method **308** on the transition cookie secret key **360** and the transition cookie data element **330**, such as an RC5 algorithm described in IETF RFC 2040 "The RC5, RC5-CBC, RC5-CBC-Pad, and RC5-CTS Algorithms" section 1 "Overview", and sections 2-8 with detailed explanations, incorporated herein by reference. The RC5 algorithm takes a 32-bit plaintext input and a 128-bit encryption key to generate a 32-bit ciphertext output. The transition cookie generator **245** uses the transition cookie data element **330** as the plaintext input to the RC5 algorithm, and the transition cookie secret key **360** as the encryption key input to the RC5 algorithm. The transition cookie generator **245** stores the resulting 32-bit ciphertext output of the RC5 algorithm in the encrypted data element **370**.

Next, the transition cookie generator **245** performs an unsigned binary addition on an encrypted data element **370** and the sequence number **318**, and stores the result in the transition cookie **250**. For example, if the encrypted data element **370** has a value of "0025BC83" in hexadecimal format, and the sequence number **318** has a value of "0743BD55" in hexadecimal format, the result of the addition is hexadecimal "076979D8". After the addition, the transition cookie **250** has a value of "076979D8" in hexadecimal. In another example, if the encrypted data element **370** has a value of "BE43D096" in hexadecimal format, and the sequence number **318** has a value of "9A275B84" in hexadecimal format, the result of the addition, and the value of transition cookie **250** is hexadecimal "1586B2C1A", with the most significant bit carried beyond the 32-bit boundary.

In another embodiment, a transition cookie generator **245** may use different steps to generate a transition cookie secret key **360**. For example, a secret key offset **301** may be an integer of a different bit length, such as a 4-bit integer value, a 3-bit integer value, or a 5-bit integer value. Also, a transition cookie generator **245** may use a secret key offset **301** to select a non-negative integer value of a different bit length from a first data item **340**. For example, a transition cookie generator **245** may select a 4-bit non-negative integer value, a 7-bit non-negative integer value, or a 5-bit non-negative value from a first data item **340**.

In other embodiments, a transition cookie generator **245** may store a second data item **350** in the least significant 64 bits (bit **0-63**) of a transition cookie secret key **360** or store second data item **350** in the most significant 64 bits (bit **64-127**) of a transition cookie secret key **360**.

A transition cookie generator **245** may also perform an exclusive-or operation on the most significant 48 bits (bit **0-47**) of a first data item **340** and the least significant 48 bits (bit **48-95**) of a first data element **340** to form a 48-bit temporary data element (not shown). Similarly, in another embodiment, a transition cookie generator **245** may perform an exclusive-or operation on the 48 even bits (bit **0**, **2**, **4**, . . . **90**, **92**, **94**) and the 48 odd bits (bit **1**, **3**, **5**, . . . **93**, **95**, **97**) to form a 48 bit temporary data element. In yet another embodiment, a transition cookie generator **245** may store a 48-bit temporary data element in the least significant 48 bits (bit **0-47**) and the most significant 48 bits (bit **80-127**) of a transition cookie secret key **360**, and set bit **48-79** to "0", or store a 48-bit temporary data element in the least significant 48 bits (bit **0-47**) of a transition cookie secret key **360**, and set the most significant 80 bits (bit **48-127**) of a transition cookie secret key **360** to "0".

In other embodiments of the invention, a transition cookie generator **245** may use an encryption algorithm to generate a transition cookie secret key **360** from the first data item **340**.

In another embodiment, a transition cookie generator **245** includes a secret key and an encryption algorithm, and uses a first data element **340** as a plaintext input, and a secret key as an encryption key input to the encryption algorithm to generate a 128-bit ciphertext output. Next, a transition cookie generator **245** generates a transition cookie secret key **360** as a 128-bit ciphertext output. Alternatively, the ciphertext output may be a 96-bit data element, and a transition cookie generator **245** stores a 96-bit ciphertext output in the least significant 96 bits (bit **0-95**) of a transition cookie secret key **360**, and sets the most significant 32 bits (bit **96-127**) to "0". In another alternative, a transition cookie generator **245** stores the least significant 32 bits (bit **0-31**) of a 96-bit ciphertext output in the most significant 32 bits (bit **96-127**) of a transition cookie secret key **360**.

As seen in FIG. **2**, a transition cookie validator **275** validates a candidate transition cookie **270** generated from a session ACK packet **230** received by the TCP session setup module **104**. An exemplary method for validating a candidate transition cookie **270** by a transition cookie validator **275** may include multiple steps as illustrated in FIGS. **4**a-**4**d.

FIG. **4**a illustrates exemplary steps for generating a candidate encrypted data element **470** by a transition cookie validator **275** based on data obtained from a received session ACK packet **230**. The candidate encrypted data element **470** may be a 32-bit data element generated based on the sequence number **418** of the TCP header in the received session ACK packet **230**, and the candidate transition cookie **270** generated from the received session ACK packet **230** as illustrated in FIG. **2**.

The candidate sequence number **428** may be a 32-bit data element generated by a transition cookie validator **275** such that the sum of candidate sequence number **428** and a value of "1" equals the sequence number **418**.

The candidate encrypted data element **470** is generated by the transition cookie validator **275** such that the result of performing an unsigned binary addition of the candidate encrypted data element **470** and the candidate sequence number **428** equals the candidate transition cookie **270**.

FIG. **4**b illustrates exemplary steps for generating a candidate transition cookie secret key **460** by the transition cookie validator **275** based on data obtained from the received session ACK packet **230** and a candidate sequence number **428**. The data used for generating the candidate transition cookie secret key **460** may include at least a source IP address **412** of the IP header in a received session ACK packet **230**, a destination port **414** and a source port **416** of the TCP header in a received session ACK packet **230**. In the process, a 96-bit first data item **440** is formed by a transition cookie validator **275** by concatenating a source IP address **412**, a candidate sequence number **428**, a source port **416**, and a destination port **414**. For example, if the source IP address **412** is 192.168.1.134, having a hexadecimal representation of "C0A80186", the candidate sequence number **428** is hexadecimal "9A275B84", the source port **416** is 4761, having a hexadecimal representation of "1299", and the destination port **414** is 240, having a hexadecimal representation of "00F0", after the concatenation, the first data item **440** has a hexadecimal value of "C0A801869A275B84129900F0".

Next, the 128-bit candidate transition cookie secret key **460** is generated from a first data item **440** by a transition cookie validator **275** using a hash function. In an embodiment, a transition cookie validator **275** uses a 6-bit secret key offset **401** to select a 6-bit non-negative integer from a first data item **440** starting at a bit indicated by secret key offset **401**. For example, if the secret key offset **401** has a value of "12" and the first data item **440** is "C0A801869A275B84129900F0", the transition cookie validator **275** selects a 6-bit non-negative integer from the first data item **440** starting at bit **12** (bits **12-17**), selecting the non-negative integer "16". The transition cookie validator **275** then generates a 64-bit second data item **350** by using the selected non-negative integer to select 64 bits of data from the first data item **440**, starting at the bit indicated by the selected non-negative integer.

For example, if the selected non-negative integer is "8" and the first data item **440** has a hexadecimal value of "C0A801869A275B84129900F0", the transition cookie validator **275** selects 64 bits (bit **8-71**) of the first data item **440** to generate a second data item **450** having a hexadecimal value of "869A275B84129900". In another example, if the first data item **440** has a hexadecimal value of "C0A801869A275B84129900F0", and the selected non-negative integer is "52", the transition cookie validator **275** selects 64 bits (bit **52-95** and bit **0-19**) in a wrap-around fashion. Bits **52-95** have a hexadecimal value of "C0A801869A2", and bits **0-19** have a hexadecimal value of "900F0", so the generated second data item **450** has a hexadecimal value of "900F0C0A801869A2".

Next, the transition cookie validator **275** generates a candidate transition cookie secret key **460** by storing the second data item **450** in the least significant 64 bits (bit **0-63**) of the candidate transition cookie secret key **460** and setting the most significant 64 bits (bit **64-127**) to "0". For example, if the second data item **450** has a hexadecinmal value of "869A275B84129900", the candidate transition cookie secret key **460** has a hexadecimal value of "0000000000000000869A275B84129900".

FIG. **4**C illustrates exemplary steps for generating a candidate transition cookie data element **430** by a transition cookie validator **275** based on a candidate encrypted data element **470** and a candidate transition cookie secret key **460**.

In an embodiment, a transition cookie validator **275** applies a cryptographic method **408** on a candidate transition cookie secret key **460** and a candidate encrypted data element **470**. An exemplary cryptographic method **408** is an RC5 algorithm described in IETF RFC 2040 "The RC5, RC5-CBC, RC5-CBC-Pad, and RC5-CTS Algorithms" section 1 "Overview", and sections 2-8 with detailed explanations, incorporated herein by reference. The RC5 algorithm takes a 32-bit ciphertext input and a 128-bit decryption key to generate a 32-bit plaintext output. A transition cookie validator **275** uses a candidate encrypted data element **470** as a ciphertext input to the RC5 algorithm, and a candidate transition cookie secret key **460** as a decryption key input to the RC5 algorithm, to generate a 32-bit candidate transition cookie data element **430** as the plaintext output of the RC5 decryption algorithm.

FIG. **4**d illustrates exemplary steps by a transition cookie validator **275** of validating a candidate transition cookie data element **430**. In an embodiment, a transition cookie validator **275** includes a clock **305**. The clock **305** indicates the current time of day, preferably in microseconds in a 32-bit format. The modified current time **409** is a 32-bit data element set by a transition cookie validator **275** sets to the current time indicated by clock **305**. A transition cookie validator **275** then sets the least significant 5 bits (bit **0-4**) of the modified current time **409** to "0". For example, if the modified current time **409** has a value of "89AE03F6" in hexadecimal format, after setting the least significant 5 bits to "0", the modified current time **409** has a hexadecimal value of "89AE03E0".

Next, a transition cookie validator **275** sets a 32-bit adjusted candidate transition cookie data element **431** to equal the candidate transition cookie data element **430**, and then sets the least significant 5 bits (bit **0-4**) of the adjusted candidate transition cookie data element **431** to "0". For example, if the adjusted candidate transition cookie data element **431** has a hexadecimal value of "89DB468F", after setting the least significant 5 bits to "0", the adjusted candidate transition cookie data element **431** has a hexadecimal value of "89DB4680".

The transition cookie validator **275** may then determine if the candidate transition cookie data element **430** is valid by determining if the adjusted candidate transition cookie data element **431** is within a time margin of 3 seconds of the modified current time **409**. In an embodiment, in order to determine if the adjusted candidate transition cookie data element **431** is within a time margin of 3 seconds of the modified current time **409**, the transition cookie stores the modified current time **409** in the least significant 32 bits (bit **0-31**) of a first 33-bit time data element, sets the most significant bit (bit **32**) to "0", and adds 6 seconds to the first 33-bit time data element. Adding 6 seconds is to add 6,000,000 micro seconds as represented by "5B8D80" in hexadecimal format. For example, if before the addition, the first 33-bit time data element has a hexadecimal value of "0FFFFFAE2", After the addition of "5B8D80", the first 33-bit time data element has a hexadecimal value of "1005B8862". The transition cookie validator **275** stores the adjusted candidate transition cookie data element **431** in the least significant 32 bits (bit **0-31**) of a second 33-bit time data element, sets the most significant bit (bit **32**) to "0", and adds 3 seconds to the second 33-bit time data element. Adding 3 seconds is to add 3,000,000 micro seconds as represented by hexadecimal "2DC6C0". The transition cookie validator **275** stores the modified current time **409** in the least significant 32 bits (bit **0-31**) of a third 33-bit time data element, and sets the most significant bit (bit **32**) to "0". If the second 33-bit time data element is smaller than the first 33-bit time data element and the second 33-bit time data element is larger than the third 33-bit time data element, the transition cookie validator **275** determines that the adjusted candidate transition cookie data element **431** is within 3 seconds of the modified current time **409**, and thus that the candidate transition cookie data element **430** is valid.

FIG. **5** illustrates exemplary steps of generating information based on a validated candidate transition cookie data element **430**. In an embodiment, candidate MSS **522** is an integer. A transition cookie validator **275** includes a reversed MSS table **507**, which includes information that maps a 4-bit data element to a candidate MSS **522**. A transition cookie validator **275** extracts the least significant 4-bit (bit **0-3**) data from candidate transition cookie data element **430**, maps the extracted 4-bit data to a reversed MSS table **507**, and stores the result in a candidate MSS **522**. A transition cookie validator **275** may then generate a maximum segment size option as described in IETF RFC 793 "Transmission Control Protocol" section 3.1 "Header Format", incorporated herein by reference, and sets a maximum segment size option data of the maximum segment size option to equal a candidate MSS **522**. A transition cookie validator **275** may further examine bit **4** of a candidate transition cookie data element **430**. If bit **4** of candidate transition cookie data element **430** has a value of "1", a transition cookie validator **275** may generate a sack-permitted option as described in IETF RFC 2018 "TCP Selective Acknowledgement Options" section 2, incorporated herein by reference. A TCP session setup module **104** may then send a sack-permitted option, a maximum segment size option, and data obtained from a received session ACK packet **230** to a computing module (not shown) for further processing.

There are many different encryption algorithms that use encryption keys of different bit lengths, such as, for example, 56-bit, 64-bit, 96-bit, 128-bit. These may generate ciphertext outputs of different bit lengths, for example, 96-bit, 64-bit, 128-bit, or 32-bit. Persons of ordinary skill in the cipher arts will be able to apply different methods, for example a hash function, to generate the transition cookie secret key **360** from the ciphertext output.

A transition cookie validator **275** may also use different steps to generate a candidate transition cookie secret key **460**. The steps used by a transition cookie validator **275** to generate a candidate transition cookie secret key **460** are similar to the steps used by a transition cookie generator **245** to generate a transition cookie secret key **360**.

Alternative embodiments of the invention may employ a different algorithm for the cryptographic methods **308**, **408**. In one example, the different algorithm is an RC2 algorithm described in IETF RFC 2268 "A Description of the RC2(r) Encryption Algorithm" section 1 "Introduction" and section 2-4 with detailed explanation, incorporated herein by reference. In another example, the different algorithm is a Blowfish algorithm. In one other example, the different algorithm is a Data Encryption Standards ("DES") algorithm based on Federal Information Processing Standards Publication "Data Encryption Standard (DES) FIPS PUB 46-3", which is incorporated herein by reference in its entirety. Other algorithms are also usable.

Also, a transition cookie validator **275** may use different time margins of modified current time **409** to determine if the candidate transition cookie data element is valid. Different time margins include but are not limited to 1 second, 4 seconds, 6 seconds, 2 seconds, or 11 seconds.

In an embodiment, the method of generating a transition cookie includes MD5 signature option information in the TCP options field. When this method is used, the method of validating a candidate transition cookie **270** correspondingly includes the MD5 signature option information in the TCP options field.

In another embodiment, transition cookie generator **245** may include a plurality of transition cookie generation methods for generating transition cookie **250**. For example, the secret key offset **301** may have a different value, such as an integer value of different bit length, such as 4-bit, or 8-bit. In other examples, the selected non-negative integer from first data item **340** may be of different bit length, such as 8-bit, or 10-bit, the cryptographic method **308** may be a different algorithm than RC5, or the generating of transition cookie data element **330** may include MD5 signature option information in the TCP options field of session SYN packet **210**. A transition cookie generation method may include steps different from the steps in the exemplary method illustrated in FIGS. **3a-3c**.

In an embodiment, the transition cookie generator **245** may selects method to generate transition cookie **250** based on random data.

The random data may include time. In one embodiment, transition cookie generator **245** selects a method based on the time of day. Alternatively, the transition cookie generator **245** may select a method after a time period, such as 10 seconds, 30 seconds, 2 minutes or 3 hours.

In another embodiment, the random data may include a source IP address in session SYN packet **210**, or a destination IP address in session SYN packet **210**.

The random data may include the network interface at which a TCP session setup module **104** receives a session SYN packet **210**, or a Virtual Local Area Network (VLAN) information associated with a session SYN packet **210**.

In one embodiment, transition cookie validator **275** includes a plurality of transition cookie validation methods for validating candidate transition cookie **270**. A transition cookie validation method may include steps different from the steps in the exemplary method illustrated in FIGS. **4**a-**4**d. A transition cookie validator **275** may select a method to validate candidate transition cookie **270** based on random data.

In these embodiments it is understood to be preferred that the transition cookie validator **275** selects a complementary method to the method selected by transition cookie generator **245**.

Although the invention herein has been described with reference to particular embodiments, it is to be understood that these embodiments are merely illustrative of the principles and applications of the present invention. It is therefore to be understood that numerous modifications may be made to the illustrative embodiments and that other arrangements may be devised without departing from the spirit and scope of the present invention as defined by the appended claims.

The invention claimed is:

[1. A system for TCP SYN cookie validation at a host server comprising:

a session SYN packet receiver for receiving a session SYN packet;

a transition cookie generator operating to generate a transition cookie with the use of a transition cookie secret key, the transition cookie comprising a time value representing the actual time, wherein the transition cookie generator generates the transition cookie secret key based on data obtained from the received session SYN packet, the data obtained from the SYN packet including at least one of a source IP address of an IP header, a destination port, a source port, and a sequence number of a TCP header in the received session SYN packet, wherein the transition cookie generator concatenates the obtained data from the session SYN packet to generate a first data item of the generator and the transition cookie generator uses a first hash function to generate the transition cookie secret key from the first data item of the generator;

a session SYN/ACK packet sender for sending the transition cookie in response to the received session SYN packet;

a session ACK packet receiver for receiving a session ACK packet, the session ACK packet including a candidate transition cookie; and

a transition cookie validator, for determining whether the candidate transition cookie in the received session ACK packet comprises a time value representing a time within a predetermined time interval from the time the session ACK packet is received, wherein the transition cookie validator generates a candidate transition cookie secret key based on data obtained from the received session ACK packet, the data obtained from the ACK packet including at least one of a source IP address of the IP header, a destination port, and a source port, wherein the transition cookie validator concatenates the obtained data from the session ACK packet to generate a first data item of the validator and the transition cookie validator uses the first or another hash function to generate the candidate transition cookie secret key from the first data item of the validator,

wherein at least one of:

the transition cookie generator uses a secret key offset to select one or more bits of data from the first data item of the generator in order to generate a second data item of the generator, and

the transition cookie validator uses a candidate secret key offset to select one or more bits of data from the first data item of the validator in order to generate a second data item of the validator.**]**

[2. The system according to claim **1**, in which the transition cookie validator determines that the received session ACK packet is valid if the candidate transition cookie in the received session ACK packet comprises a time value representing a time within a predetermined time interval from the time the session ACK packet is received.**]**

[3. The system according to claim **1**, in which the predetermined time interval is in the range of one to six seconds.**]**

[4. The system according to claim **1**, in which the predetermined time interval is three seconds.**]**

[5. The system according to claim **1**, in which the generating of the transition cookie includes the use of random data.**]**

[6. The system according to claim **1**, in which the generating of the transition cookie includes the use of data obtained from the session SYN packet.**]**

[7. A system for TCP SYN cookie validation at a host server comprising:

a session SYN packet receiver for receiving a session SYN packet;

a transition cookie generator operating to generate a transition cookie with the use of a transition cookie secret key, the transition cookie comprising a time value representing the actual time, wherein the transition cookie generator generates the transition cookie by (i) generating an encrypted data element of the generator by applying a cryptographic method on the transition cookie secret key and a transition cookie data element, (ii) performing an unsigned binary addition on the encrypted data element of the generator and a sequence number of a TCP header in the received session SYN packet, and (iii) storing the result in the transition cookie;

a session SYN/ACK packet sender for sending the transition cookie in response to the received session SYN packet;

a session ACK packet receiver for receiving a session ACK packet, the session ACK packet including a candidate transition cookie; and

a transition cookie validator, for determining whether the candidate transition cookie in the received session ACK packet comprises a time value representing a time within a predetermined time interval from the time the session ACK packet is received.**]**

[8. The system according to claim **7**, wherein the transition cookie data element comprises data based on at least one of: a selective ACK, an MSS index, and a 32-bit current time of day indicated by a clock.**]**

[9. A system for TCP SYN cookie validation at a host server comprising:

a session SYN packet receiver for receiving a session SYN packet;

a transition cookie generator operating to generate a transition cookie with the use of a transition cookie secret key, the transition cookie comprising a time value representing the actual time;

a session SYN/ACK packet sender for sending the transition cookie in response to the received session SYN packet;

a session ACK packet receiver for receiving a session ACK packet, the session ACK packet including a candidate transition cookie; and

a transition cookie validator, for determining whether the candidate transition cookie in the received session ACK packet comprises a time value representing a time within a predetermined time interval from the time the session ACK packet is received, wherein the transition cookie validator generates:

a candidate sequence number such that a sequence number of a TCP header in the received session ACK packet equals the sum of the candidate sequence number and a value of 1,

a candidate encrypted data element such that the result of performing an unsigned binary addition of the candidate encrypted data element and a candidate sequence number equals the candidate transition cookie, and

a candidate transition cookie data element by applying a cryptographic method on a candidate transition cookie secret key and the candidate encrypted data element.]

[10. The system according to claim 9, wherein the transition cookie validator validates the candidate transition cookie data element by adjusting the candidate transition cookie data element to generate, and determining if the adjusted candidate transition cookie data element is within a predetermined time margin of a modified current time.]

11. A system for TCP SYN cookie validation at a host server, the system comprising:

at least one processor and a memory storing:

a session SYN packet receiver, wherein when the session SYN packet receiver is executed by the at least one processor, the session SYN packet receiver causing the at least one processor to receive a session SYN packet;

a transition cookie generator, the transition cookie generator being executed by the at least one processor to generate a transition cookie with the use of a transition cookie secret key, the transition cookie comprising a time value representing the actual time;

a session SYN/ACK packet sender, the session SYN/ACK packet sender being executed by the at least one processor to send the transition cookie in response to the received session SYN packet;

a session ACK packet receiver, the session ACK packet receiver being executed by the at least one processor to receive a session ACK packet, the session ACK packet including a candidate transition cookie; and

a transition cookie validator, the transition cookie validator being executed by the at least one processor to determine whether the candidate transition cookie in the received session ACK packet comprises a time value representing a time within a predetermined time interval from the time the session ACK packet is received; and

wherein:

the transition cookie generator is executed by the at least one processor to generate the transition cookie secret key based on data obtained from the received session SYN packet;

the transition cookie validator is executed by the at least one processor to generate a candidate transition cookie secret key based on data obtained from the received session ACK packet;

the transition cookie generator is executed by the at least one processor to concatenate the obtained data from the session SYN packet to generate a first data item of the generator;

the transition cookie validator is executed by the at least one processor to concatenate the obtained data from the session ACK packet to generate a first data item of the validator;

the transition cookie generator is executed by the at least one processor to use a secret key offset to select one or more bits of data from the first data item of the generator in order to generate a second data item of the generator, and

the transition cookie validator is executed by the at least one processor to use a candidate secret key offset to select one or more bits of data from the first data item of the validator in order to generate a second data item of the validator.

12. The system according to claim 11, wherein:

when the transition cookie secret key is generated based on data obtained from the received session SYN packet, the obtained data includes at least one of: a source IP address of an IP header, a destination port, a source port, and a sequence number of a TCP header in the received session SYN packet, and

when the candidate transition cookie secret key is generated based on data obtained from the received session ACK packet, the obtained data includes at least one of:

a source IP address of the IP header, a destination port, and a source port.

13. The system according to claim 11, wherein at least one of:

the transition cookie generator is executed by the at least one processor to use a first hash function to generate the transition cookie secret key from the first data item of the generator, and

when the transition cookie validator is executed by the at least one processor to use the first or another hash function to generate the candidate transition cookie secret key from the first data item of the validator.

14. The system according to claim 11, in which the transition cookie validator is executed by the at least one processor to determine that the received session ACK packet is valid if the candidate transition cookie in the received session ACK packet comprises a time value representing a time within a predetermined time interval from the time the session ACK packet is received.

15. The system according to claim 11, in which the predetermined time interval is in the range of one to six seconds.

16. The system according to claim 11, in which the predetermined time interval is three seconds.

17. The system according to claim 11, in which the generating of the transition cookie includes the use of random data.

18. The system according to claim 11, in which the generating of the transition cookie includes the use of data obtained from the session SYN packet.

19. A system for TCP SYN cookie validation at a host server, the system comprising:

at least one processor and a memory storing:

a session SYN packet receiver, wherein the session SYN packet receiver is executed by the at least one processor to receive a session SYN packet;

a transition cookie generator, wherein the transition cookie generator is executed by the at least one processor to generate a transition cookie with the use of a

transition cookie secret key, the transition cookie comprising a time value representing the actual time;

a session SYN/ACK packet sender, wherein the session SYN/ACK packet sender is executed by the at least one processor to send the transition cookie in response to the received session SYN packet;

a session ACK packet receiver, wherein when the session ACK packet receiver is executed by the at least one processor to receive a session ACK packet, the session ACK packet including a candidate transition cookie; and

a transition cookie validator, wherein the transition cookie validator is executed by the at least one processor to determine whether the candidate transition cookie in the received session ACK packet comprises a time value representing a time within a predetermined time interval from the time the session ACK packet is received; and wherein:

the transition cookie generator is executed by the at least one processor to generate the transition cookie by (i) generating an encrypted data element of the generator by applying a cryptographic method on the transition cookie secret key and a transition cookie data element, (ii) performing an unsigned binary addition on the encrypted data element of the generator and a sequence number of a TCP header in the received session SYN packet, and (iii) storing the result in the transition cookie.

20. The system according to claim 19, wherein the transition cookie data element comprises data based on at least one of: a selective ACK, an MSS index, and a 32-bit current time of day indicated by a clock.

21. The system according to claim 19, in which the transition cookie validator is executed by the at least one processor to determine that the received session ACK packet is valid if the candidate transition cookie in the received session ACK packet comprises a time value representing a time within a predetermined time interval from the time the session ACK packet is received.

22. The system according to claim 19, in which the predetermined time interval is in the range of one to six seconds.

23. The system according to claim 19, in which the predetermined time interval is three seconds.

24. The system according to claim 19, in which the generating of the transition cookie includes the use of random data.

25. The system according to claim 19, in which the generating of the transition cookie includes the use of data obtained from the session SYN packet.

26. A system for TCP SYN cookie validation at a host server, the system comprising:

at least one processor and a memory storing:

a session SYN packet receiver, wherein the session SYN packet receiver is executed by the at least one processor to receive a session SYN packet;

a transition cookie generator, wherein the transition cookie generator is executed by the at least one processor to generate a transition cookie with the use of a transition cookie secret key, the transition cookie comprising a time value representing the actual time;

a session SYN/ACK packet sender, wherein the session SYN/ACK packet sender is executed by the at least one processor to send the transition cookie in response to the received session SYN packet;

a session ACK packet receiver, wherein the session ACK packet receiver is executed by the at least one processor to receive a session ACK packet, the session ACK packet including a candidate transition cookie; and

a transition cookie validator, wherein the transition cookie validator is executed by the at least one processor to determine whether the candidate transition cookie in the received session ACK packet comprises a time value representing a time within a predetermined time interval from the time the session ACK packet is received; and to generate:

a candidate sequence number such that a sequence number of a TCP header in the received session ACK packet equals the sum of the candidate sequence number and a value of 1,

a candidate encrypted data element such that the result of performing an unsigned binary addition of the candidate encrypted data element and a candidate sequence number equals the candidate transition cookie, and

a candidate transition cookie data element by (i) applying a cryptographic method on a candidate transition cookie secret key and the candidate encrypted data element.

27. The system according to claim 26, wherein the transition cookie validator is executed by the at least one processor to validate the candidate transition cookie data element by adjusting the candidate transition cookie data element to generate, and determining if the adjusted candidate transition cookie data element is within a predetermined time margin of a modified current time.

28. The system according to claim 26, in which when the transition cookie validator is executed by the at least one processor to determine that the received session ACK packet is valid if the candidate transition cookie in the received session ACK packet comprises a time value representing a time within a predetermined time interval from the time the session ACK packet is received.

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