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(54) **PROXY DETECTION SYSTEMS AND METHODS**

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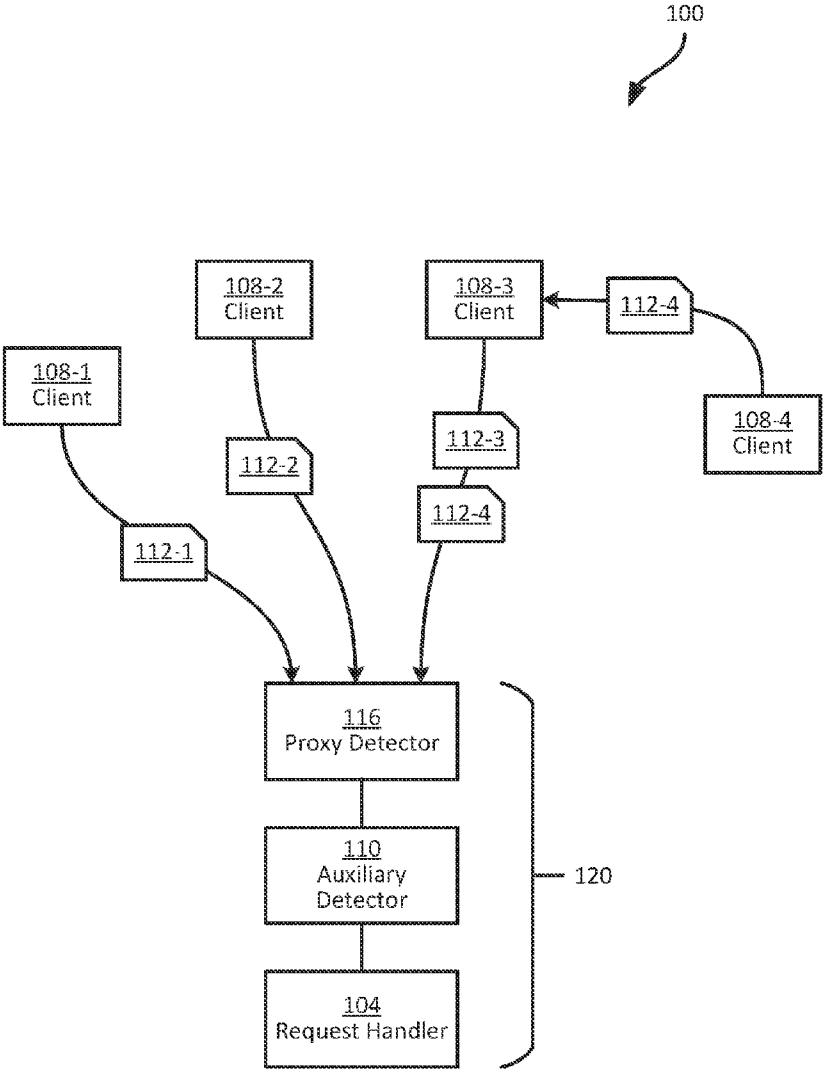
(57) **ABSTRACT**

A proxy detection method includes: in response to receiving, from a client device, a first request to establish a transport-layer connection between the client device and the server, transmitting a first message to the client device according to a first handshake sequence, for establishing the transport-layer connection; determining a first time period associated with completion of the first handshake sequence; in response to receiving, from the client device over the transport-layer connection, a second request to establish a secure link between a client endpoint and the server, transmitting a second message to the client endpoint according to a second predefined handshake sequence, for establishing the secure link; determining a second time period associated with completion of the second handshake sequence; and generating, based on the first time period and the second time period, a score indicating a likelihood that the client device is a proxy for the client endpoint.



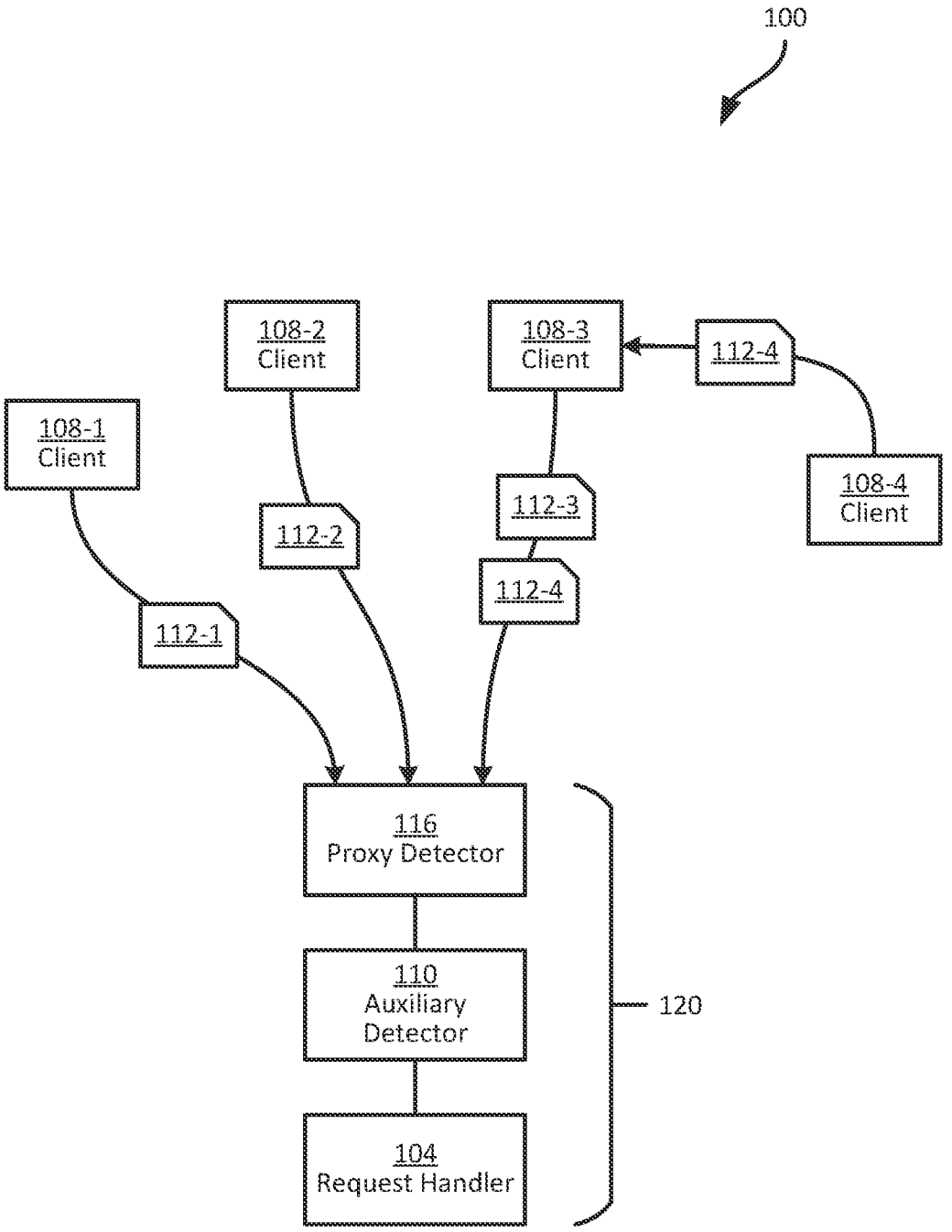

100
108-2
Client
108-3
Client
112-4
108-1
Client
108-4
Client
112-3
112-2
112-4
112-1
116
Proxy Detector
110
Auxiliary
Detector
120
104
Request Handler

FIG. 1

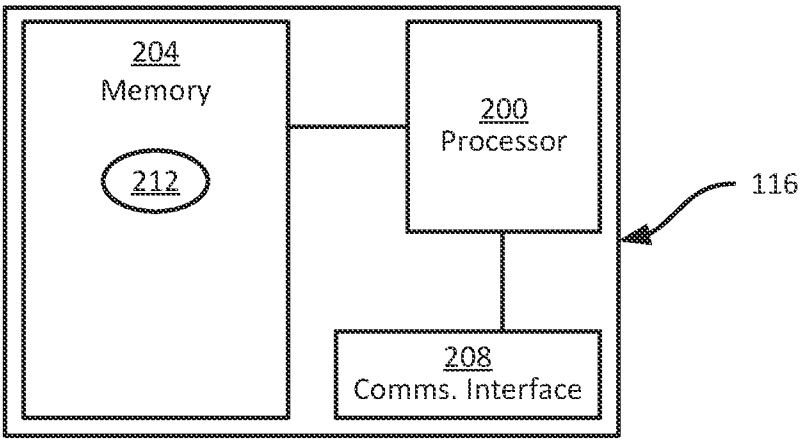


FIG. 2

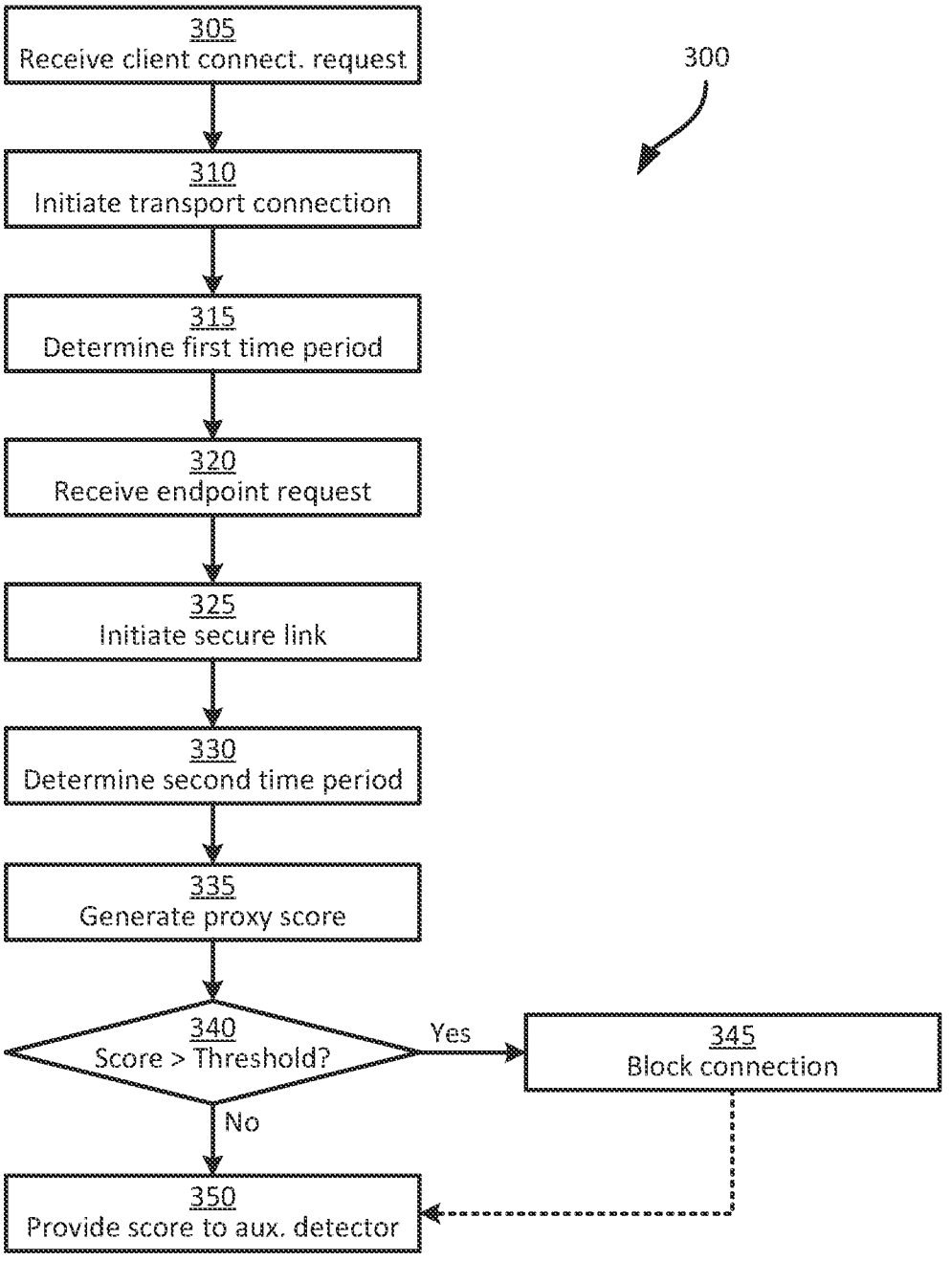

305
Receive client connect. request
300
310
Initiate transport connection
315
Determine first time period
320
Receive endpoint request
325
Initiate secure link
330
Determine second time period
335
Generate proxy score
340
Score > Threshold?
Yes
345
Block connection
No
350
Provide score to aux. detector

FIG. 3

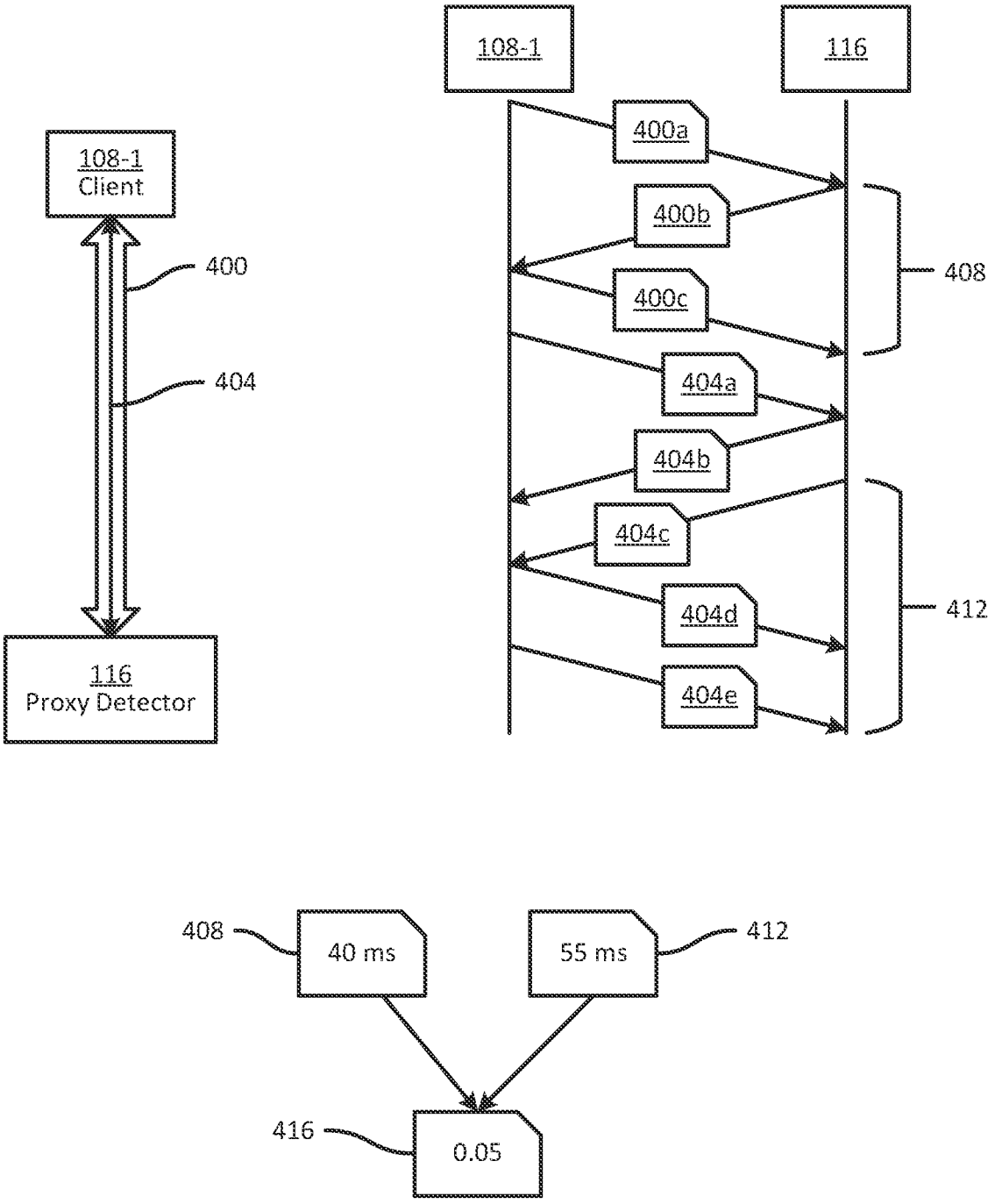

108-1
Client
400
404
116
Proxy Detector
108-1
116
400a
400b
400c
404a
404b
404c
404d
404e
408
412
408
40 ms
55 ms
412
416
0.05

FIG. 4

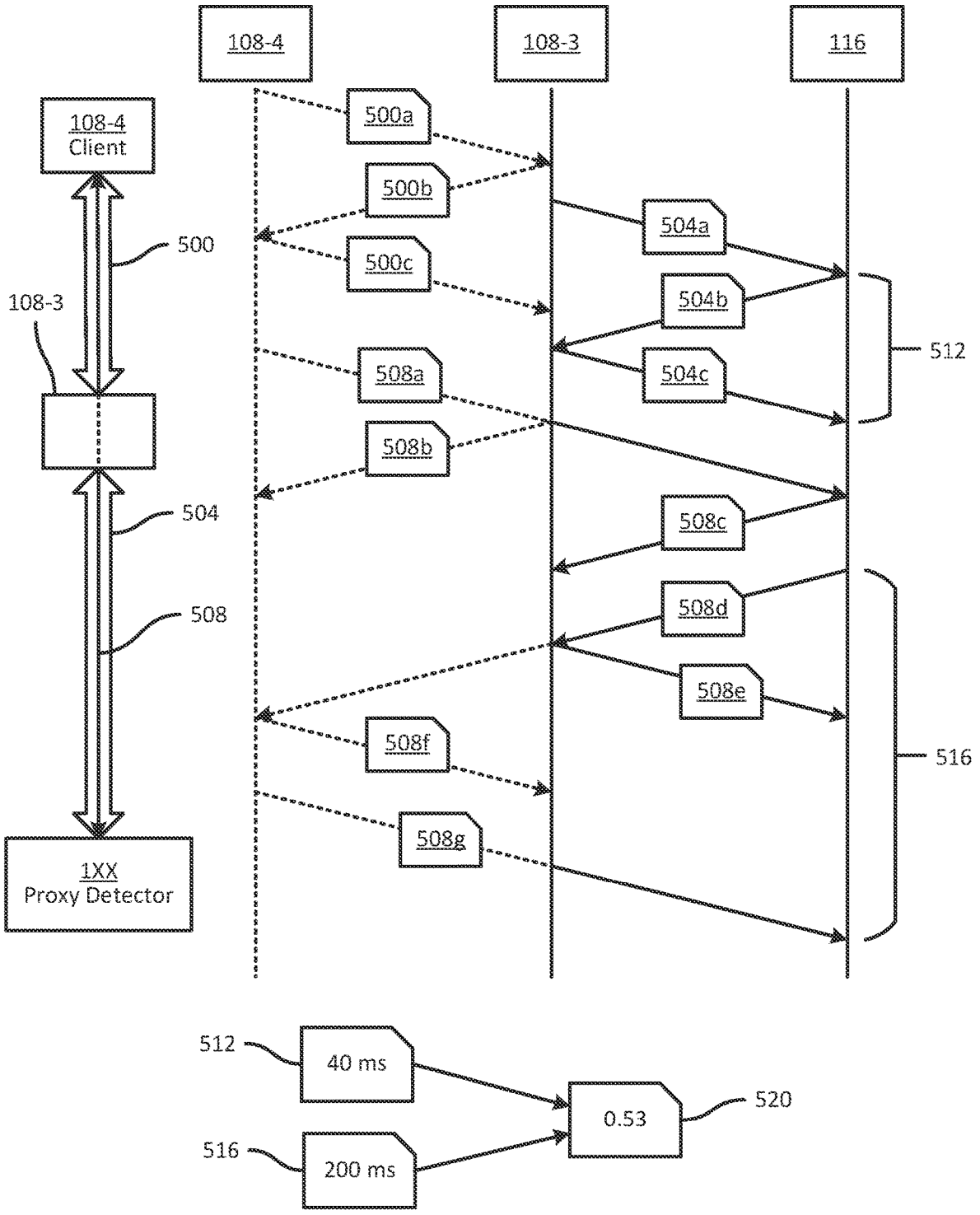

108-4
108-3
116
108-4
Client
500a
500b
500c
504a
504b
504c
512
500
108-3
508a
508b
504
508c
508
508d
508e
508f
516
508g
1XX
Proxy Detector
512
40 ms
0.53
520
516
200 ms

FIG. 5

PROXY DETECTION SYSTEMS AND METHODS

BACKGROUND

[0001] Servers receive and respond to requests from client devices, e.g., to deliver data requested by the client devices in connection with web-based services. For certain services, responding to such requests can be computationally intensive. For example, servers handling search requests for travel-related services (e.g., flights, hotels, and the like) may incur significantly higher computational costs to generate responses to such requests than the costs incurred by other servers responsible for the retrieval of previously generated and indexed data.

[0002] The operators of the above-mentioned servers may derive little or no return for the cost of servicing fraudulent or abusive client requests. Upon detecting such requests, discarding or otherwise altering the usual request handling process may therefore be desirable, to reduce the allocation of computational resources to responding to such requests, with little likelihood of return, e.g., in the form of travel services being purchased from the server's operator. Fraudulent or abusive client requests, however, may be routed through proxy devices, which complicates their detection. Detecting such requests may be particularly challenging when the proxy devices are residential or other consumer-level devices that may also originate legitimate requests.

SUMMARY

[0003] An aspect of the specification provides a proxy detection method in a server, the method including: in response to receiving, from a client device, a first request to establish a transport-layer connection between the client device and the server, transmitting a first message to the client device according to a first handshake sequence, for establishing the transport-layer connection; determining a first time period associated with completion of the first handshake sequence; in response to receiving, from the client device over the transport-layer connection, a second request to establish a secure link between a client endpoint and the server, transmitting a second message to the client endpoint according to a second predefined handshake sequence, for establishing the secure link; determining a second time period associated with completion of the second handshake sequence; and generating, based on the first time period and the second time period, a score indicating a likelihood that the client device is a proxy for the client endpoint.

[0004] Another aspect of the specification provides a server, including: a communications interface; and a processor configured to: in response to receiving, from a client device, a first request to establish a transport-layer connection between the client device and the server, transmit a first message to the client device according to a first handshake sequence, for establishing the transport-layer connection; determine a first time period associated with completion of the first handshake sequence; in response to receiving, from the client device over the transport-layer connection, a second request to establish a secure link between a client endpoint and the server, transmit a second message to the client endpoint according to a second handshake sequence, for establishing the secure link; determine a second time period associated with completion of the second handshake sequence; and generate, based on the first time period and the second time period, a score indicating a likelihood that the client device is a proxy for the client endpoint.

BRIEF DESCRIPTIONS OF THE DRAWINGS

[0005] Embodiments are described with reference to the following figures.

[0006] FIG. **1** is a diagram illustrating a communications system.

[0007] FIG. **2** is a diagram illustrating certain internal components of the proxy detector of FIG. **1**.

[0008] FIG. **3** is a flowchart of a proxy detection method.

[0009] FIG. **4** is a diagram illustrating an example performance of the method of FIG. **3**.

[0010] FIG. **5** is a diagram illustrating another example performance of the method of FIG. **3**.

DETAILED DESCRIPTION

[0011] FIG. **1** depicts a communications system **100**, including a request handler **104** and a plurality of client devices, referred to collectively as client devices **108** and generically as a client device **108**. In the illustrated example, the system **100** includes four client devices **108-1**, **108-2**, **108-3**, and **108-4**, although it will be understood that the system **100** can include greater and smaller numbers of client devices **108** in other examples. The client devices **108** are computing devices such as desktop computers, smart phones, laptop computers, or the like. Each client device **108** thus includes suitable hardware elements, such as processing, storage and network communications components, as well as input and output devices (e.g., keyboards, touch panels, displays, and the like), enabling the client device **108** to communicate with the request handler **104** over a network or combination of networks. Communications between the client devices **108** and the request handler **104** include the transmission of requests from client devices **108** to the request handler **104**, and the generation and transmission of responses to such requests from the request handler **104** to the relevant client devices **108**.

[0012] The request handler **104** can be implemented as a server or set of servers, configured to receive and process requests from the client devices **108**. The request handler **104** therefore includes processing and storage hardware components, e.g., executing suitable software to receive and interpret client requests, as well as to generate and return response data to such requests. The requests may include, for example, search requests for travel-related goods or services, such as search requests for flights between specified origin and destination locations (e.g., particular cities or airports), on specified days, or the like. In order to generate response data for a client request, the request handler **104** can be configured to retrieve and process data from various repositories and/or interact with other computing devices (e.g., operated by airlines, or the like), to generate combinations of flights that satisfy search parameters set out in the client request.

[0013] The generation of response data can be computationally complex, as the availability and pricing of flights may be highly variable and dependent on the identity of an operator of the client device **108**, among other factors. The costs (e.g., in terms of financial commitments, staffing, and the like) of the computational resources (e.g., processing time, storage capacity, and the like) allocated to handling

search requests from the client devices **108** may be supported in part by purchases of the above-mentioned flights by operators of the client devices **108**. Some client requests, however, are highly unlikely to lead to such purchases, and committing computational resources to generate responses to those requests may therefore not be desirable.

[0014] For example, some client requests are originated by scraper bots, and the results generated by the request handler **104** may be used to populate third-party search engines, storefronts, or the like, thus potentially depriving the operator of the request handler **104** of at least some of the financial return associated with those search results, while still having incurred the computational cost of generating the search results. As will be apparent to those skilled in the art, bot-originated requests are not the only type of client request that it may be desirable to detect and handle differently from other client requests. Such requests are simply discussed herein as an illustrative example.

[0015] Bot-originated requests such as those mentioned above, and/or other client requests that the operator of the request handler **104** may seek to detect and handle differently from other requests, may be detected based on the content of the requests, attributes of the requests' senders, or the like. The system **100** may include, for example, an auxiliary detector **110**, e.g., in the form of an additional server or set of servers, and/or additional application(s) expected by the request handler **104**. The auxiliary detector **110** is configured to process incoming requests **112** to determine whether each request **112** is likely to have originated from a bot or other source for which differential handling is desired (e.g., sources presenting security risks, engaging in fraudulent behavior, or the like). A request may therefore be forwarded to the request handler **104** for further processing, for example, only if the auxiliary detector **110** determines a low likelihood that the request originated from a bot.

[0016] Bot-originated requests, however, may be obfuscated from detection by the auxiliary detector **110** by routing such requests through proxies. For example, the client devices **108-1** and **108-2** are shown transmitting respective requests **112-1** and **112-2** to the request handler **104** in FIG. **1**; the requests **112-1** and **112-2** are generated at the client devices **108-1** and **108-2** themselves. The client device **108-3**, on the other hand, is shown transmitting distinct requests **112-3** and **112-4** to the request handler **104**. The request **112-3** may be generated at the client device **108-3**, e.g., via input data provided by an operator of the client device **108-3**. The request **112-4**, however, originated not at the client device **108-3**, but at a distinct client device **108-4** employing the client device **108-3** as a proxy. In some examples, additional computing devices may handle the request **112-4** between the client device **108-4** and the client device **108-3**. For example, a superproxy (not shown) can be configured to receive instructions from the client device **108-4** (e.g., executing a scraper bot application) and generate numerous individual requests for transmission via distinct proxies such as the client device **108-3**.

[0017] Various mechanisms are available to detect proxied requests **112** (e.g., filtering requests based on blacklisted Internet Protocol (IP) addresses, or the like). Those mechanisms, however, may only detect a portion of proxied requests. Further, effectiveness of those detection mechanisms may be reduced for certain forms of proxied request. In the illustrated system, for example, the client device **108-3** is referred to as a residential proxy, in that the client device **108-3** is a consumer-level computing device that is unlikely to trigger conventional proxy-detection mechanisms. The client device **108-3**, as seen above, can also originate legitimate (e.g., not bot-originated) requests that are preferably processed by the request handler **104** in the same manner as the requests **112-1** and **112-2**, in addition to proxied requests for which modified handling may be desirable.

[0018] To detect proxied requests in general, and requests routed via residential proxies in particular, the system **100** therefore also includes a proxy detector **116**. The proxy detector **116** can be implemented as a distinct computing device (e.g., one or more servers) from the auxiliary detector **110** and the request handler **104**. In other examples, the proxy detector **116** can be implemented as an additional software application executed at the computing device(s) implementing the auxiliary detector **110** or the request handler **104**. As will be discussed below in greater detail, the proxy detector **116** is deployed as the first entity in the request-handing infrastructure (labelled as a request-handling subsystem **120** in FIG. **1**) with which the client devices **108** communicate. That is, transport-layer connections and secure links are established between the client devices **108** and the proxy detector **116**, rather than between the client devices **108** and the auxiliary detector **110** or request handler **104**.

[0019] As will be apparent, the client requests **112** are generally implemented as sequences of messages, e.g., to establish communications between a client device **108** and the proxy detector **116**, to serve web content or the like to the client device **108**, and to receive the above-mentioned search request from the client device. Establishing communications between a client device **108** and the proxy detector **116** typically involves establishing a transport-layer connection, e.g., based on the Transport Control Protocol (TCP) or another suitable transport-layer protocol. Once the transport-layer connection is established, a secure link is established over the transport-layer connection, e.g., based on the Transport Layer Security (TLS) protocol, Secure Sockets Layer (SSL) protocol, or the like. Web content, search requests, response data and the like, can then be exchanged over the secure link.

[0020] The proxy detector **116** is configured to inspect at least some of the above-mentioned messages to determine whether the client device **108** is likely to be operating as a proxy. In particular, as will be discussed below in greater detail, the transport-layer connection is established between the proxy detector **116** and the client device **108** as the nearest transport-layer device (i.e., ignoring routing hardware implementing link-layer and other lower-level functions). The secure link, however, is established with the ultimate client endpoint, e.g., the device executing the web browser or other application that initiated communication with the subsystem **120** via the proxy.

[0021] In the case of non-proxied requests, the nearest transport-layer device and the client endpoint are one and the same, e.g., the client device **108-1** for the request **112-1**. In the case of proxied requests, however, the client endpoint does not reside at the nearest transport-layer device. In the context of FIG. **1**, for example, the nearest transport-layer device involved in transmission of the client request **112-4** is the client device **108-3**, but the client endpoint is the client device **108-4**. The proxy detector **116** is configured, via the

above-mentioned message inspection, to determine round-trip time periods associated with the transport-layer connection and the secure link, and to assess whether the client device **108** is likely to be operating as a proxy based on those time periods. Of particular note, the proxy detector **116** can perform the above-mentioned inspection and assessment without modifying the messages themselves or the processes by which the client devices **108** establish communications with the subsystem **120** (e.g., without delivering executable code or other content to the client devices **108** that would not have been delivered in the absence of the proxy detector **116**).

[0022] Before discussing the operation of the system **100**, and in particular the functionality of the proxy detector **116**, in greater detail, certain internal components of the proxy detector **116** will be described with reference to FIG. **2**.

[0023] As noted above, the proxy detector **116** can be implemented as a server in the subsystem **120**, distinct from the auxiliary detector **110** and the request handler **104**. In the illustrated example, the proxy detector **116** includes at least one processor **200**, such as a central processing unit (CPU) or the like. The processor **200** is interconnected with a memory **204**, implemented as a suitable non-transitory computer-readable medium (e.g., a suitable combination of non-volatile and volatile memory subsystems including any one or more of Random Access Memory (RAM), read only memory (ROM), Electrically Erasable Programmable Read Only Memory (EEPROM), flash memory, magnetic computer storage, and the like). The processor **200** and the memory **204** are generally comprised of one or more integrated circuits (ICs).

[0024] The processor **200** is also interconnected with a communications interface **208**, which enables the proxy detector **116** to communicate with the other computing devices of the system **100**. The communications interface **208** therefore includes any necessary components (e.g., network interface controllers (NICs), radio units, and the like) to enable such communication. The proxy detector **116** can also include input and output devices connected to the processor **200**, such as keyboards, mice, displays, and the like (not shown). In other examples, input and output devices can be connected to the proxy detector **116** remotely, via another computing device (not shown).

[0025] The components of the proxy detector **116** mentioned above can be deployed in a single enclosure, or in a distributed format. In some examples, therefore, the proxy detector **116** includes a plurality of processors, either sharing the memory **204** and communications interface **208**, or each having distinct associated memories and communications interfaces. Implementing the proxy detector **116** in a distributed format can enable scaling of the computational resources available to the proxy detector **116**, geographic distribution of the functionality provided by the proxy detector **116**, and the like.

[0026] The memory **204** stores a plurality of computer-readable programming instructions, executable by the processor **200**. The instructions stored in the memory **204** include a proxy detection application **212**, execution of which by the processor **200** configures the processor **200** to perform various functions related to the above-mentioned inspection and assessment of message exchanged with the client devices **108** to detect client devices **108** operating as proxies. In some examples, the application **212** can be implemented as a set of distinct applications, e.g., a packet sniffer application to collect incoming and outgoing messages, and an analysis application to assess the above-mentioned time periods.

[0027] In other examples, as noted earlier, the proxy detector **116** can be implemented on computing hardware shared with either or both of the auxiliary detector **110** and the request handler **104**. For example, the memory **304** can store not only the application **212**, but also one or more other applications implementing the functionality of the detector **110** and/or request handler **104**. In such embodiments, the application **212** is configured as the endpoint for communications addressed to the illustrated computing platform. That is, the application **212**, and not the applications implementing auxiliary detection and/or response handling, is configured to handle the establishment of communications with client devices **108**. Configuring the application **212** (or the proxy detector **116** more generally, if the proxy detector **116** is implemented in distinct hardware from the other components of the subsystem **120**) as the endpoint enables the application **212** to inspect messages transmitted by the nearest transport-layer device, as well as the client endpoint.

[0028] Turning to FIG. **3**, a method **300** of proxy detection is illustrated. The method **300** will be described below in conjunction with its performance in the system **100**, and in particular by the proxy detector **116**, e.g., via execution of the application **212** by the processor **200**.

[0029] At block **305**, the proxy detector **116** is configured to receive a first request from a client device **108**. The first request is a request to establish a transport-layer connection between the client device **108** and the proxy detector **116**, e.g., a TCP-based connection as noted earlier. The request may include, for example, a TCP 'SYN' message containing a sequence number, an identifier of the client device **108**, or the like.

[0030] At block **310**, in response to the first request received at block **305**, the proxy detector **116** is configured to send a message (or the first in a series of messages, depending on the protocol employed to establish the transport-layer connection) to the client device **108**, according to a handshake sequence defined by the relevant protocol. Turning briefly to FIG. **4**, the client device **108-1** and the proxy detector **116** are shown in isolation, along with a sequence diagram illustrating various messages exchanged between the client device **108-1** and the proxy detector **116**.

[0031] In particular, to establish a transport-layer connection **400**, the client device **108-1** sends a first request **400***a* (e.g., the above-mentioned SYN message) to the proxy detector **116**. The proxy detector **116**, upon receiving the request **400***a* at block **305**, can store a timestamp representing the time at which the request **400***a* was received. At block **310**, the proxy detector **116** transmits a message **400***b*, such as a SYN-ACK message (in TCP-based embodiments), containing an acknowledgement of the request **400***a*, as well as a sequence number and/or other relevant information. The handshake sequence continues with a further message **400***c* from the client device **108-1**, e.g., acknowledging the message **400***b*. In this example, following receipt of the message **400***c* at the proxy detector **116**, the transport-layer connection **400** is established, and can be used to exchange other data, e.g., to establish a secure link **404**, discussed further below. As will be apparent to those skilled in the art, the handshake sequence used to establish the connection **400** need not be exactly as discussed above, depending on the protocol employed to establish the connection **400**.

[0032] The proxy detector **116** is also configured to store timestamps representing the time at which the message **400***b* was sent, and the time at which the message **400***c* was received. Returning to FIG. **3**, at block **315** the proxy detector **116** is configured to determine a first time period, e.g., associated with the above-mentioned handshake sequence. In this example, at block **315** the proxy detector **116** is configured to determine a time period elapsed between the transmission of the message **400***b* (i.e., the initiation of block **310**), and receipt of the message **400***c*. The measured time period, as will now be apparent, represents the round trip time (RTT) between the client device **108-1** and the proxy detector **116**, and is illustrated as a time period **408** in FIG. **4**. Although the RTT measurement at block **315** is discussed in connection with the handshake sequence for establishing the connection **400**, in other examples the RTT can be determined after the connection **400** is established, e.g., from any other suitable pair of messages exchanged between the client device **108-1** and the proxy detector **116**. A suitable pair of messages is a pair in which the first originates at the proxy detector **116**, and the second necessarily follows the first and is expected to be transmitted by the client device **108-1** substantially immediately upon receipt of the first.

[0033] Returning to FIG. **3**, at block **320** the proxy detector **116** is configured to receive a second request, to establish a secure link over the transport-layer connection (e.g., the connection **400** shown in FIG. **4**). The secure link is between a client endpoint and the proxy detector **116**, although it is not yet known whether the client endpoint is co-located with the client device **108** (i.e., with the device **108** from which the request at block **305** was received).

[0034] In response to the second request at block **320**, the proxy detector **116** is configured to transmit a message initiating a handshake sequence according to a selected protocol, to establish a secure link with the client endpoint. In the present example, the protocol employed to establish the secure link is the TLS protocol, although other suitable protocols may be employed. It will be apparent that the handshake sequence involved in establishing the secure link will vary with the protocol employed at block **325**.

[0035] Returning to FIG. **4**, to establish the secure link **404** over the connection **400**, the client device **108-1** can transmit a request **404***a*, such as a 'Client Hello' message as defined in the TLS protocol. For example, the request **404***a* can contain an indication of the supported protocol version (e.g., TLS 1.2 or 1.3), indications of cipher suites supported by the client device **108-1**, a random number (e.g., for generation of a shared master secret, later used to generate encryption keys) and the like.

[0036] In response to the message **404***a*, the proxy detector **116** transmits a message **404***b*, such as an acknowledgment of the message **404***a*, to the client device **108-1**. The proxy detector **116** can then transmit one or more further messages as dictated by the handshake sequence defined by the relevant security protocol. For simplicity of illustration, FIG. **4** shows one additional message **404***c* sent by the proxy detector **116**. The message **404***c* can include, for example, the 'Server Hello' message as defined in the TLS protocol. The message **404***c* can contain a protocol version and cipher suites supported by the proxy detector **116**, a further random number for later use in key generation. The message **404***c* can also include a server certificate, or the like.

[0037] In response to the message **404***c*, the client device **108-1** returns an acknowledgement message **404***d*, and can then send a final message **404***e* to complete the handshake sequence, such as a 'Change cipher' message in the TLS 1.3 protocol, or a 'Client key exchange' message in the TLS 1.2 protocol.

[0038] Referring again to FIG. **3**, at block **330** the proxy detector **116** is configured to determine a second time period associated with the above-mentioned handshake sequence to establish the secure link **404**. As noted earlier in connection with block **315**, the proxy detector **116** is configured to maintain timestamps associated with the transmission of the messages **404***b* and **404***c*, as well as with the receipt of the messages **404***a*, **404***d*, and **404***e*. The time period determined at block **330** represents a round-trip time for the establishment of the secure link **404**. That is, the RTT measured at block **330** is the time elapsed between the transmission of a message by the proxy detector **116**, and the receipt of a following message (e.g., expected to be transmitted substantially immediately by the client endpoint in response to the message from the proxy detector **116**) from the client endpoint. In the example shown in FIG. **4**, the proxy detector **116** determines a second time period **412** elapsed between transmission of the message **404***c*, and receipt of the message **404***e*.

[0039] Of particular note, although the example shown in FIG. **4** involves determining the second time period based on messages exchanged during the handshake sequence, in other examples the time period can be determined based on other messages, after establishment of the secure link **404**. The messages employed to determine the RTT at block **330** are selected, however, to ensure that they travel between the proxy detector **116** and the client endpoint, whether or not the client endpoint is behind a proxy. Thus, certain messages, such as acknowledgement messages, may not be suitable for use at block **330** because they cannot be guaranteed to have originated at the client endpoint. In the example of FIG. **4**, the messages **404***c* and **404***e* are employed because the information contained in those messages is required to establish the secure link **404**, and therefore cannot be generated by an intermediate proxy.

[0040] Upon determining the second time period **325**, the proxy detector **116** is configured to generate a score indicating a likelihood that the client device **108** (e.g., the client device **108-1**, in the example of FIG. **4**) is operating as a proxy for the client endpoint. In other examples, the determination at block **315** can be performed substantially simultaneously with the determination at block **330**, given that the proxy detector **116** can store timestamps associated with the messages exchanged during the above-mentioned handshake sequences and/or subsequent communications with the client device **108**.

[0041] Generation of the score at block **335** is based on the first and second time periods, i.e., on the RTT associated with the transport-layer connection **400**, and the RTT associated with the secure link **404**. Turning to FIG. **4**, solely for illustrative purposes, the first time period is assumed to be forty milliseconds, and the second time period is assumed to be fifty-five milliseconds. These time periods are provided byway of example only, and it will be apparent that varying network conditions between client devices **108** and the proxy detector **116** may lead to a wide variety of other time periods. However, it is expected that non-proxied client

requests exhibit smaller differences between the first and second time periods than proxied client requests.

[0042] The score determined at block **335**, therefore, assesses whether a difference between the first and second time periods indicates that the client device **108** with which the transport-layer connection is established is operating as a proxy for the client endpoint with which the secure link is established.

[0043] A wide variety of mechanisms for determining the score at block **335** are contemplated. For example, returning to FIG. **5**, the proxy detector can determine a difference between the time periods **408** and **412** (e.g., fifteen milliseconds, in this example), and normalize that difference to a predefined range, based on a configurable maximum difference. For instance, the proxy detector can normalize the difference of fifteen milliseconds to a range between zero and one, with one representing a difference of three hundred milliseconds or more (e.g., the score can be capped at a value of one). In the illustrated example, therefore, the proxy detector **116** generates a score **416** of 0.05 (i.e., 15 ms/300).

[0044] In other examples, the score can be the difference itself, without normalization. In further examples, the score can be generated by determining the sum of the two time periods, and/or by normalizing the sum according to a predefined range. Various other mechanisms will also occur to those skilled in the art for generating the score. Any mechanism selected for generating the score at block **335** reflects the fact that when the transport-layer connection is established with a client device **108** that is also the client endpoint for the secure link subsequently established over the transport-layer connection, the separation between first and second time periods is expected to be relatively small. In contrast, when the transport-layer connection is established with a client device **108** that is not the client endpoint, the separation between the first and second time periods is expected to be greater. Thus, the score-generation mechanism is selected to produce higher (or lower) scores for greater differences between time periods, and lower (or higher) scores for smaller differences between time periods.

[0045] Following generation of the score at block **335**, the proxy detector **116** can select a handling action for the client request **112**, and/or for subsequent client requests **112** using the same secure link. For example, at block **340**, the proxy detector **116** can be configured to compare the score to a threshold. In examples in which higher scores indicate higher likelihoods of proxying, therefore, the proxy detector **116** can determine whether the score exceeds a previously defined threshold. When the determination is affirmative, indicating that the relevant client device **108** is likely operating as a proxy, the proxy detector **116** can discard subsequent requests over the secure link at block **345**, block/terminate the secure link previously established, or the like.

[0046] When the determination at block **340** is negative, the proxy detector **116** can forward any client requests received over the secure link to the auxiliary detector **110** and/or request handler **104**, along with the score, at block **350**. In some examples, blocks **340** and **345** are omitted, and the proxy detector **116** simply forwards the score and request(s) to the auxiliary detector **110**. The auxiliary detector **110** can be configured to determine whether the request (s) are likely to have been generated by a bot, based at least in part on the score.

[0047] Turning to FIG. **5**, another example performance of the method **300** is illustrated, to contrast with the performance shown in FIG. **4**, in which the client device **108-1** itself is both the nearest transport-layer device and the client endpoint for secure communications. In FIG. **5**, on the other hand, the client device **108-3** acts as a proxy for the client device **108-4**.

[0048] Prior to receipt of a request a the proxy detector **116** at block **305**, the client device **108-4** initiates a transport-layer connection **500** with the client device **108-3**, e.g., via a three-way handshake sequence implemented via the messages **500***a* (e.g., a SYN message), **500***b* (e.g., a SYN-ACK message), and **500***c* (e.g., an ACK message). Either after establishment of the connection **500**, or (as illustrated) contemporaneously with establishment of the connection **500**, the client device **108-1** initiates a transport-layer connection **504** with the proxy detector **116**. Specifically, at block **305** the proxy detector receives a message **504***a* (e.g., a SYN message). At block **310**, via the messages **504***b* and **504***c*, the proxy detector **116** and the client device **108-3** complete the establishment of the connection **504**. At block **315**, the proxy detector **116** determines a first time period **512** associated with the transport-layer connection **504**, such as the RTT between transmission of the message **504***b* and receipt of the message **504***c*.

[0049] Once the connections **500** and **504** are established, the client device **108-4** can request establishment of a secure link **508** over the connections **500** and **504**. Of particular note, the secure link **508** tunnels through the client device **108-3**, and therefore cannot be initiated by the client device **108-3** itself. As a proxy, the client device **108-3** is configured only to route encrypted communications between the client device **108-4** and the proxy detector **116**, using the connections **500** and **504** (but without accessing the contents of such communications).

[0050] At block **320**, therefore, the proxy detector **116** can receive a request **508***a* (e.g., a Client Hello message) from the client device **108-3**. The request **508***a* was originated at the client device **108-4**, although that fact is not visible to the proxy detector **116**. The client device **108-3** may acknowledge the message **508***a* to the client device **108-4** via a message **508***b*.

[0051] At block **325**, the proxy detector **116** is configured to initiate or continue the relevant handshake sequence to establish the secure link **508**. For example, as noted earlier, the proxy detector **116** can send an acknowledgement message **508***c*, which may be relayed to the client device **108-4** in some examples, but is not in the illustrated example. The proxy detector **116** can then send a message **508***d*, such as the previously mentioned Server Hello message, containing information necessary to establish the secure link **508** (e.g., supported cipher suites, and the like). The message **508***d* is relayed to the client device **108-4**, and acknowledged via the an ACK message **508***e* by the client device **108-3**. The message **508***e*, however, is not used by the proxy detector **116** to determine a time period **516** associated with the secure link **508**, because the message **508***e* cannot be guaranteed to have originated at the client endpoint. The message **508***e*, that is, does not contain information that can only be generated or otherwise provided by the client endpoint of the secure link **508**, and therefore may not (and in the illustrated example, does not) represent a true RTT between the proxy detector **116** and the client endpoint.

[0052] Once the message **508***d* is received at the client device **108-4**, the client device **108-4** may send an acknowledgement **508***f*, which is not forwarded to the proxy detector **116** in this example, but can be forwarded in other examples. The client device **108-4** then sends a message **508***g* to complete the handshake sequence and establish the secure link **508**. The message **508***g* is analogous to the message **404***e* shown in FIG. **4**. To determine the time period **516** at block **330**, the proxy detector **116** determines the time elapsed between transmission of the message **508***d*, and reception of the message **508***g*. More generally, as noted earlier, the proxy detector **116** determines the time elapsed between a message transmitted from the proxy detector **116** that necessarily terminates at the client endpoint for the secure connection **508**, and a subsequent expected message that necessarily originates at the client endpoint.

[0053] As seen in FIG. **5**, the need to relay messages between the client devices **108-3** and **108-4** increases the time elapsed to complete the secure link **508**, while the time required to complete the transport-layer connection **504** is unchanged relative to FIG. **4**. That is, the presence of a proxy does not affect the connection **504**, but lengthens the RTT associated with the secure link **508**.

[0054] To determine a score at block **335**, the proxy detector **116** can be configured, as in the example of FIG. **4**, to determine the difference between the time periods **512** and **516**, and to normalize that difference, e.g., against a maximum of three hundred milliseconds. The result, as shown in FIG. **5**, assuming values of forty milliseconds and two hundred milliseconds for the time periods **512** and **516**, is a score **520** of 0.53. That is, the score **520** is significantly higher than the score **416**, indicating a greater likelihood that the client device **108-3** is operating as a proxy.

[0055] As will be apparent, therefore, the system **100** and specifically the proxy detector **116** enables the detection of proxied client requests **112** in a manner sufficiently robust to detect residential proxies that may be challenging to detect using previous proxy-detection mechanisms, and in a manner that does not require the deployment of executable code to client devices, or any modification to the message flows between client devices **108** and the proxy detector **116**.

[0056] Specific example embodiments have been described above. Those skilled in the art, however, will understand that various modifications can be made to the above-examples, within the scope of above teachings. The scope of the claims below should therefore not be limited by the specific embodiments set forth in the above examples, but should be given the broadest interpretation consistent with the description as a whole.

[0057] Certain expressions may be employed herein to list combinations of elements. Examples of such expressions include: "at least one of A, B, and C"; "one or more of A, B, and C"; "at least one of A, B, or C"; "one or more of A, B, or C". Unless expressly indicated otherwise, the above expressions encompass any combination of A and/or B and/or C.

[0058] Those skilled in the art will further understand that in some embodiments, the functionality of the application **212** as described above may be implemented using pre-programmed hardware or firmware elements (e.g., application specific integrated circuits (ASICs), electrically erasable programmable read-only memories (EEPROMs), etc.), or other related components.

1. A proxy detection method in a server, the method comprising:

in response to receiving, from a client device, a first request to establish a transport-layer connection between the client device and the server, transmitting a first message to the client device according to a first handshake sequence, for establishing the transport-layer connection;

determining a first time period associated with completion of the first handshake sequence;

in response to receiving, from the client device over the transport-layer connection, a second request to establish a secure link between a client endpoint and the server, transmitting a second message to the client endpoint according to a second handshake sequence, for establishing the secure link;

determining a second time period associated with completion of the second handshake sequence; and

generating, based on the first time period and the second time period, a score indicating a likelihood that the client device is a proxy for the client endpoint.

2. The method of claim **1**, wherein the transport-layer connection is based on the Transport Control Protocol (TCP).

3. The method of claim **2**, wherein the first message includes a SYN-ACK message; and wherein the first time period is a time elapsed between transmission of the first message, and receipt of an ACK message from the client device.

4. The method of claim **1**, wherein the secure link is based on one of (i) the Transport Layer Security (TLS) protocol, and (ii) the Secure Sockets Layer (SSL) protocol.

5. The method of claim **4**, wherein the second time period is a time elapsed between transmission of the second message, and receipt of a next message from the client endpoint according to the second predefined handshake sequence.

6. The method of claim **1**, wherein generating the score includes determining a difference between the first and second time periods.

7. The method of claim **1**, further comprising selecting a handling action for future requests over the transport-layer connection, based on the score.

8. The method of claim **7**, wherein the handling action includes discarding the future requests when the score exceeds a threshold.

9. The method of claim **1**, further comprising providing the score to an auxiliary detector.

10. A server, comprising:

a communications interface; and

a processor configured to:

in response to receiving, from a client device, a first request to establish a transport-layer connection between the client device and the server, transmit a first message to the client device according to a first handshake sequence, for establishing the transport-layer connection;

determine a first time period associated with completion of the first handshake sequence;

in response to receiving, from the client device over the transport-layer connection, a second request to establish a secure link between a client endpoint and the server, transmit a second message to the client endpoint according to a second handshake sequence, for establishing the secure link;

determine a second time period associated with completion of the second handshake sequence; and

generate, based on the first time period and the second time period, a score indicating a likelihood that the client device is a proxy for the client endpoint.

11. The server of claim **10**, wherein the transport-layer connection is based on the Transport Control Protocol (TCP).

12. The server of claim **11**, wherein the first message includes a SYN-ACK message; and wherein the first time period is a time elapsed between transmission of the first message, and receipt of an ACK message from the client device.

13. The server of claim **10**, wherein the secure link is based on one of (i) the Transport Layer Security (TLS) protocol, and (ii) the Secure Sockets Layer (SSL) protocol.

14. The server of claim **13**, wherein the second time period is a time elapsed between transmission of the second message, and receipt of a next message from the client endpoint according to the second predefined handshake sequence.

15. The server of claim **10**, wherein the processor is configured, to generate the score, to determine a difference between the first and second time periods.

16. The server of claim **10**, wherein the processor is further configured to select a handling action for future requests over the transport-layer connection, based on the score.

17. The server of claim **16**, wherein the handling action includes discarding the future requests when the score exceeds a threshold.

18. The server of claim **10**, wherein the processor is further configured to provide the score to an auxiliary detector.

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