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(54) SYSTEM AND METHOD FOR MONITORING USER ACTIONS WITH RESPECT TO A RESOURCE PRESENTED BY A WEB BROWSER

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H04L 9/40 (2022.01)

(52) **U.S. Cl.**
CPC ***H04L 63/1425*** (2013.01); ***H04L 63/0884*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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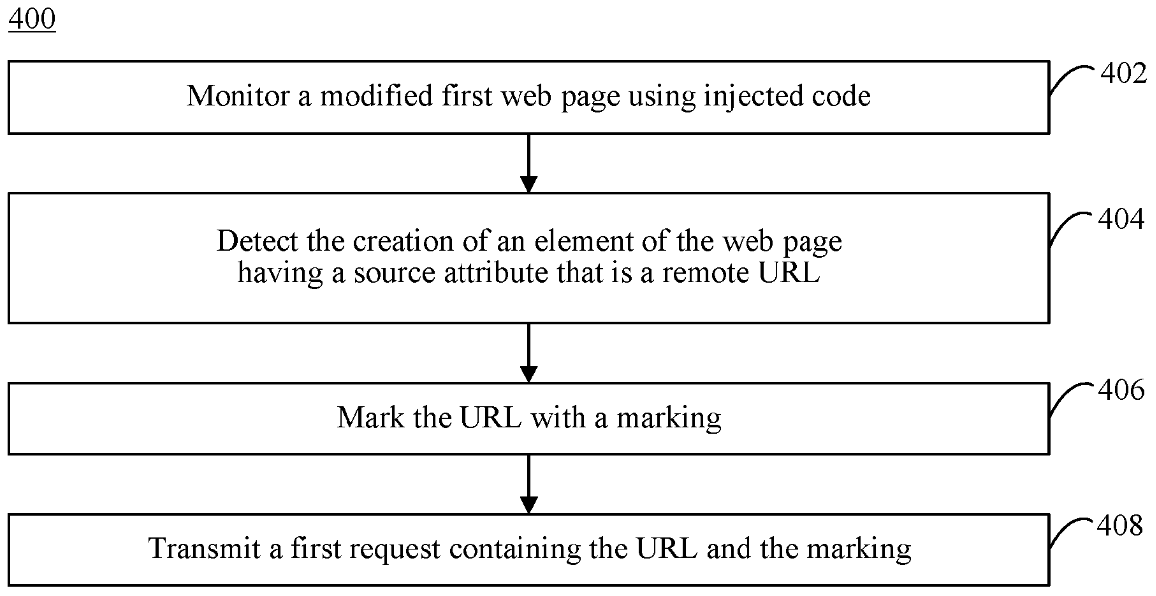
Primary Examiner — Andrew J Steinle
(74) *Attorney, Agent, or Firm* — Weaver IP L.L.C.

(57) **ABSTRACT**

Systems and methods are described for converting a resource from a first format that is normally rendered by a web browser using a file viewer that prevents monitoring user actions with respect to the resource on behalf of a proxy server into a second format that enables such monitoring. The proxy server injects code into a web page requested by the web browser to cause the web browser to mark a uniform resource locator (URL) of an element that is created by the web page. Upon detecting a request containing the marked URL, the proxy server examines the response corresponding to the request to determine if the response includes a resource in the first format. If the response includes a resource in the first format, the proxy server converts the resource into the second format and transmits the resource to the web browser in the second format.

20 Claims, 8 Drawing Sheets


400
Monitor a modified first web page using injected code
402
Detect the creation of an element of the web page having a source attribute that is a remote URL
404
Mark the URL with a marking
406
Transmit a first request containing the URL and the marking
408

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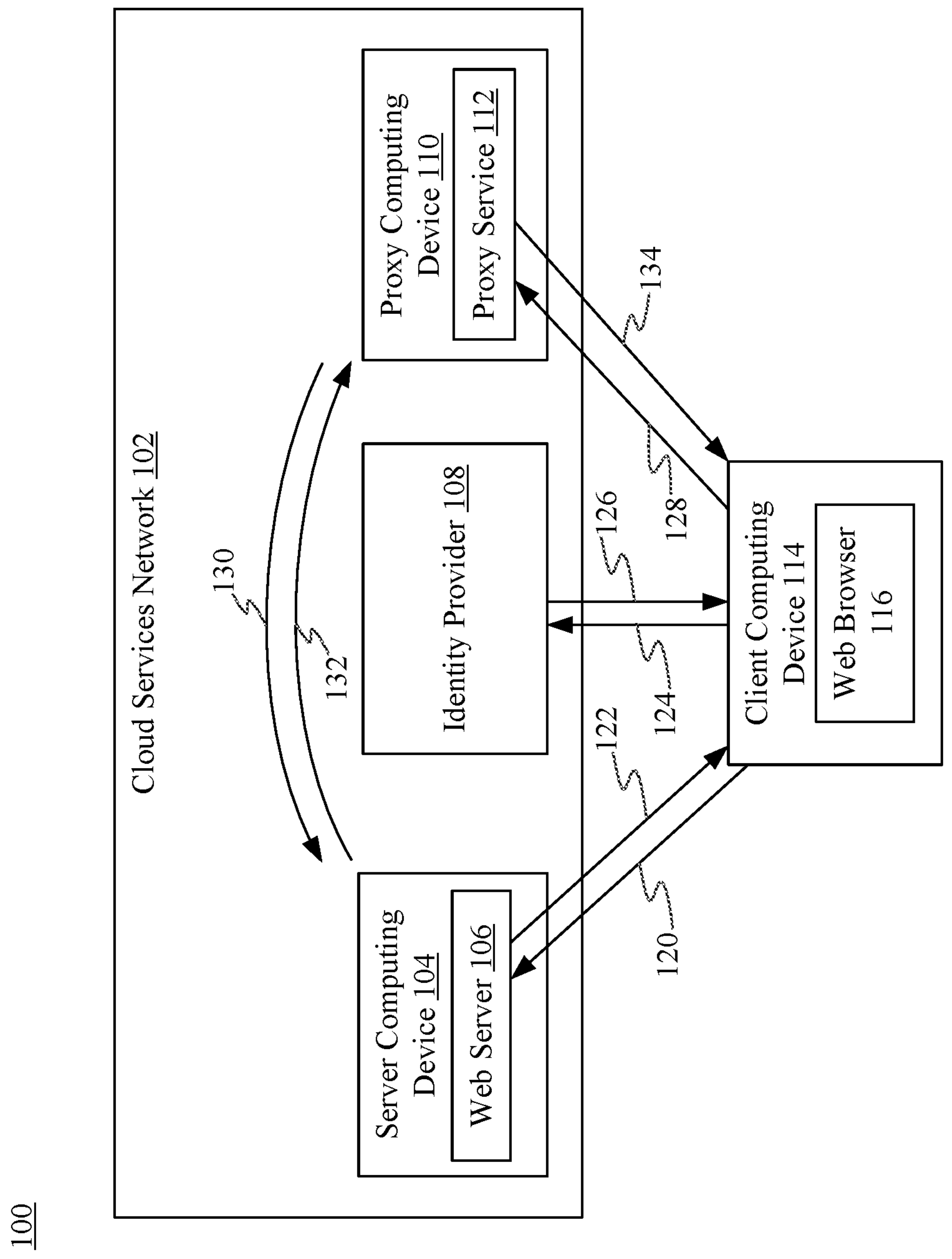
100
Cloud Services Network 102
Server Computing Device 104
Web Server 106
Identity Provider 108
Proxy Computing Device 110
Proxy Service 112
Client Computing Device 114
Web Browser 116
120
122
124
126
128
130
132
134

FIG. 1

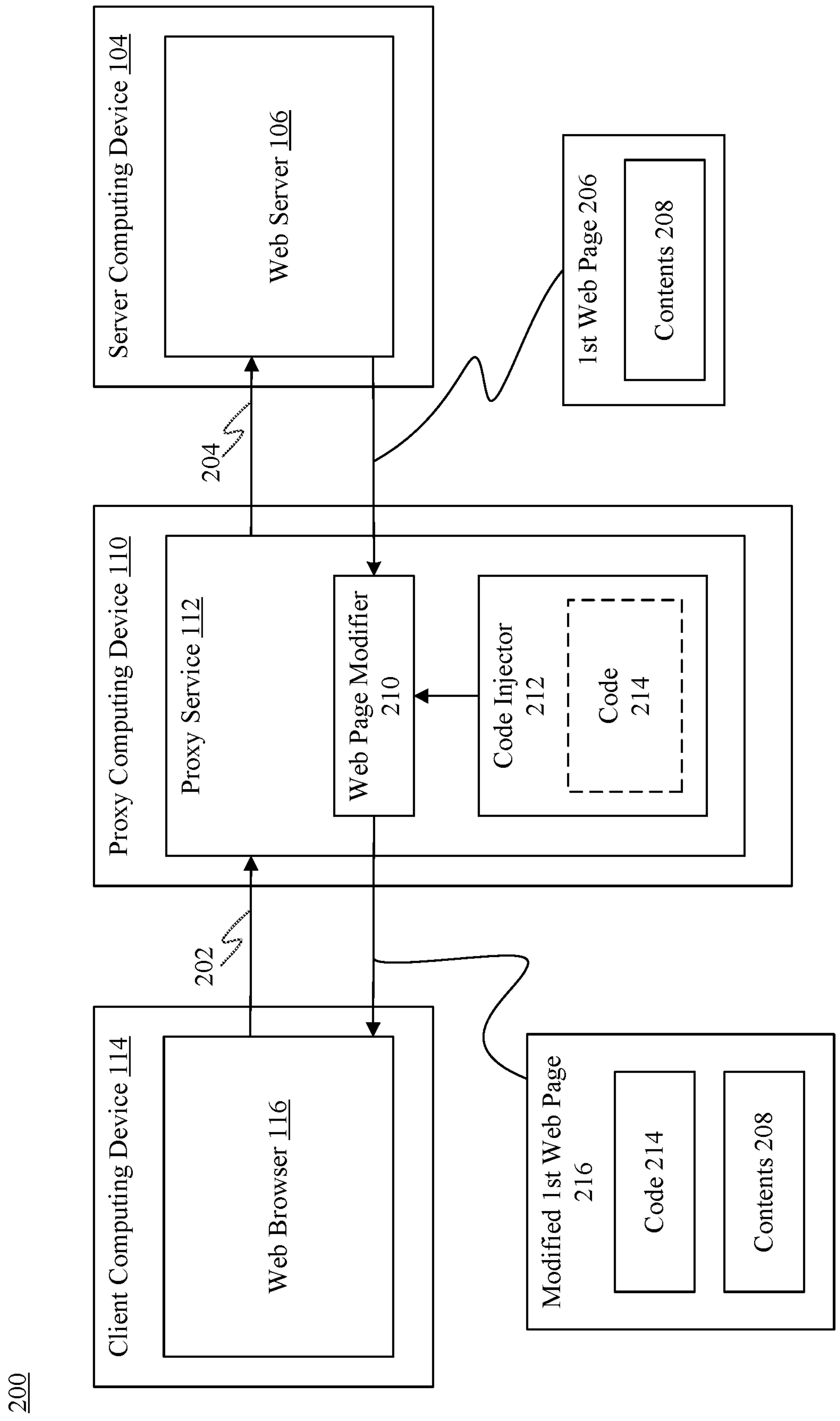
200
Client Computing Device 114
Web Browser 116
202
Proxy Computing Device 110
Proxy Service 112
Web Page Modifier 210
Code Injector 212
Code 214
204
Server Computing Device 104
Web Server 106
1st Web Page 206
Contents 208
Modified 1st Web Page 216
Code 214
Contents 208

FIG. 2

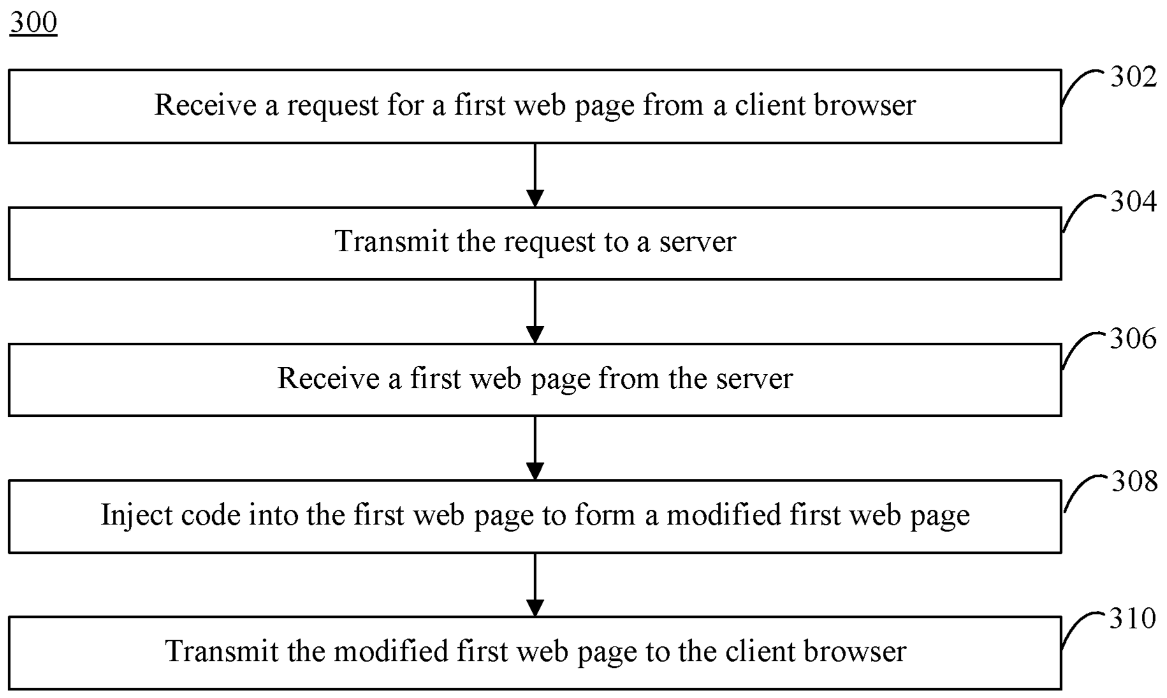
300
Receive a request for a first web page from a client browser
302
Transmit the request to a server
304
Receive a first web page from the server
306
Inject code into the first web page to form a modified first web page
308
Transmit the modified first web page to the client browser
310

FIG. 3

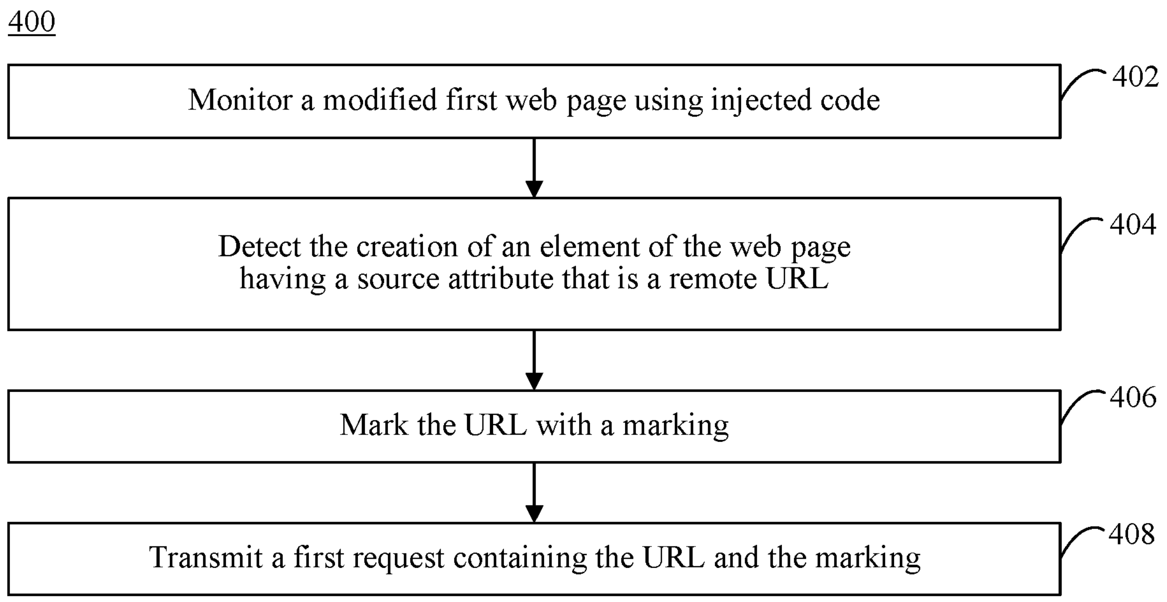
400
Monitor a modified first web page using injected code
402
Detect the creation of an element of the web page having a source attribute that is a remote URL
404
Mark the URL with a marking
406
Transmit a first request containing the URL and the marking
408

FIG. 4

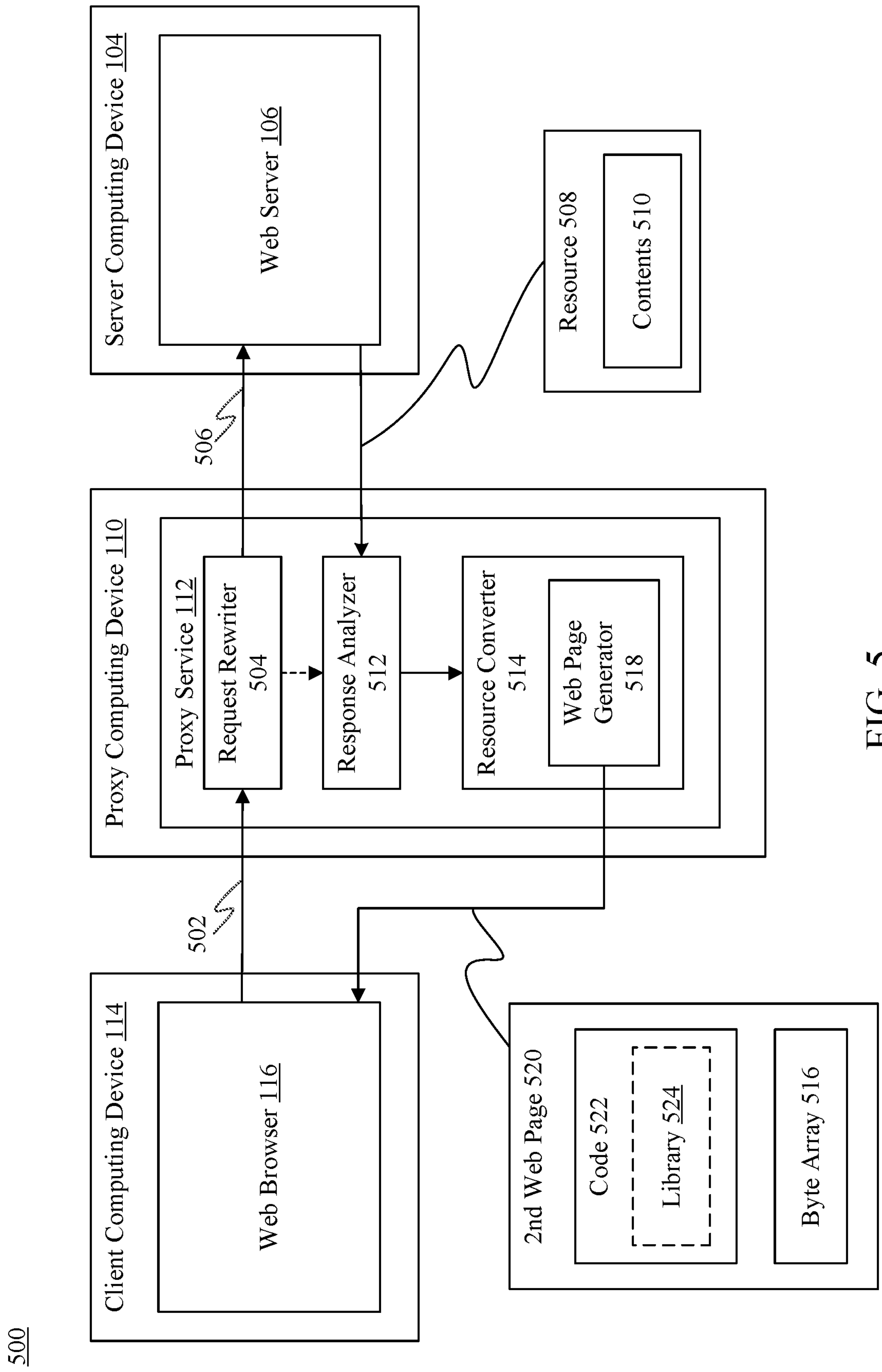
500
Client Computing Device 114
Web Browser 116
502
Proxy Computing Device 110
Proxy Service 112
Request Rewriter 504
Response Analyzer 512
Resource Converter 514
Web Page Generator 518
506
Server Computing Device 104
Web Server 106
Resource 508
Contents 510
2nd Web Page 520
Code 522
Library 524
Byte Array 516

FIG. 5

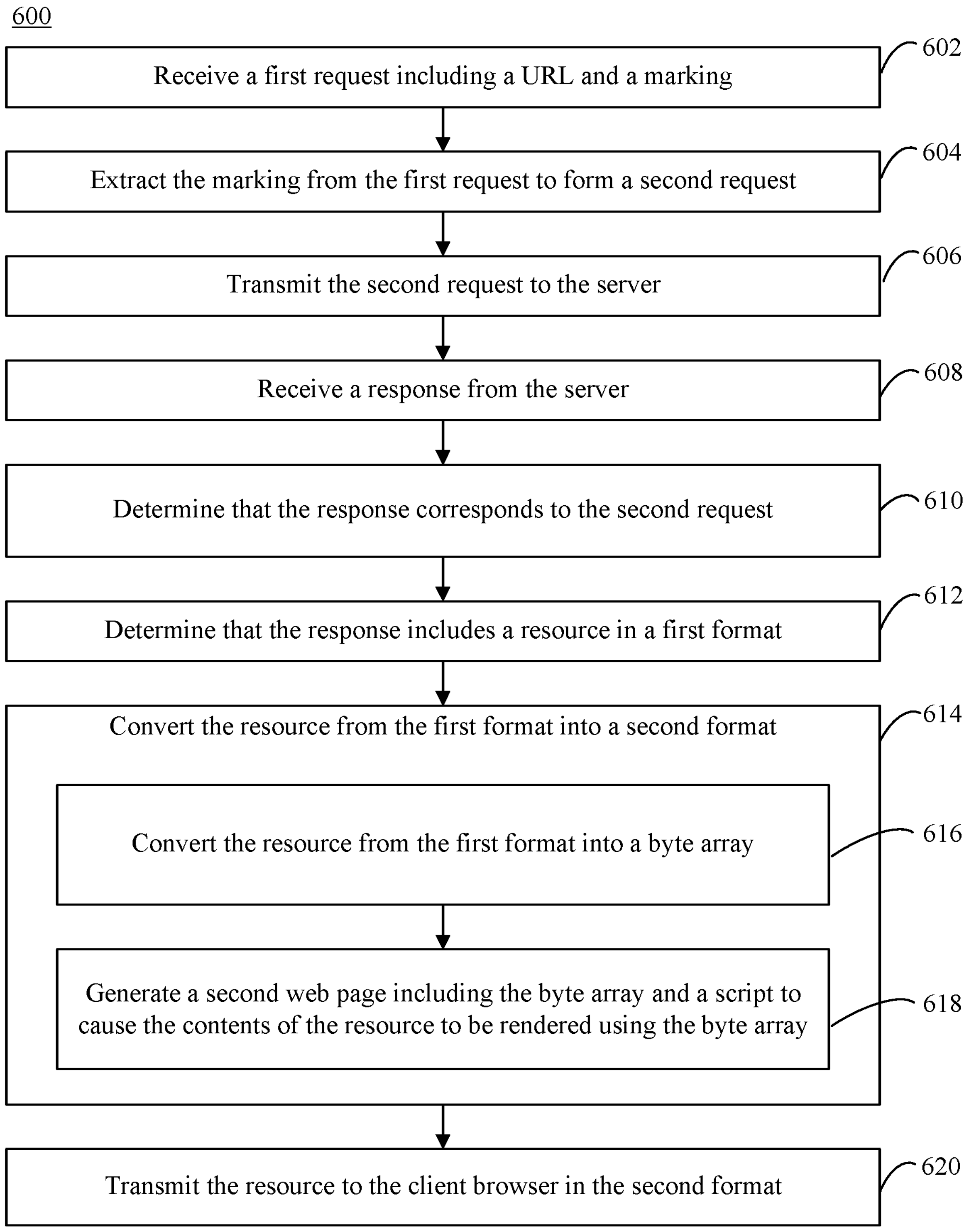
600
Receive a first request including a URL and a marking
602
Extract the marking from the first request to form a second request
604
Transmit the second request to the server
606
Receive a response from the server
608
Determine that the response corresponds to the second request
610
Determine that the response includes a resource in a first format
612
Convert the resource from the first format into a second format
614
Convert the resource from the first format into a byte array
616
Generate a second web page including the byte array and a script to cause the contents of the resource to be rendered using the byte array
618
Transmit the resource to the client browser in the second format
620

FIG. 6

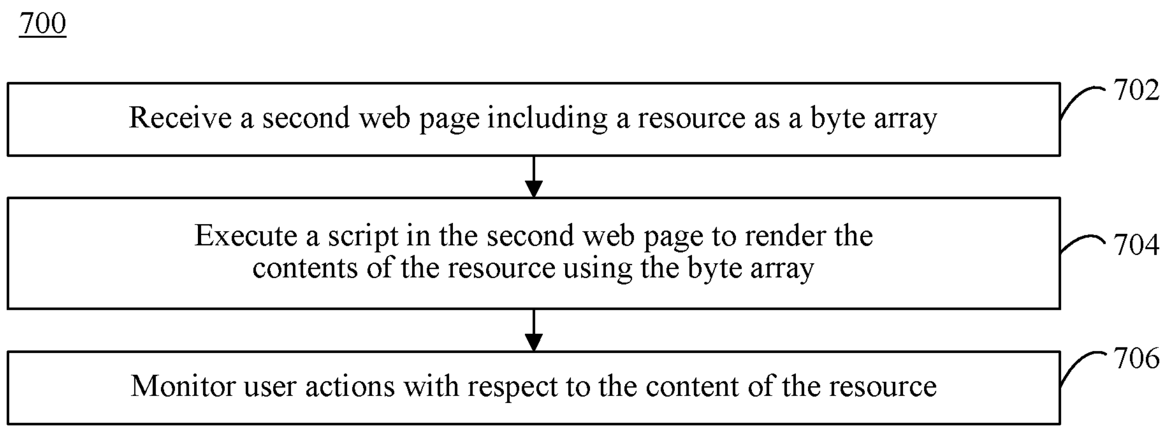
700
Receive a second web page including a resource as a byte array
702
Execute a script in the second web page to render the contents of the resource using the byte array
704
Monitor user actions with respect to the content of the resource
706

FIG. 7

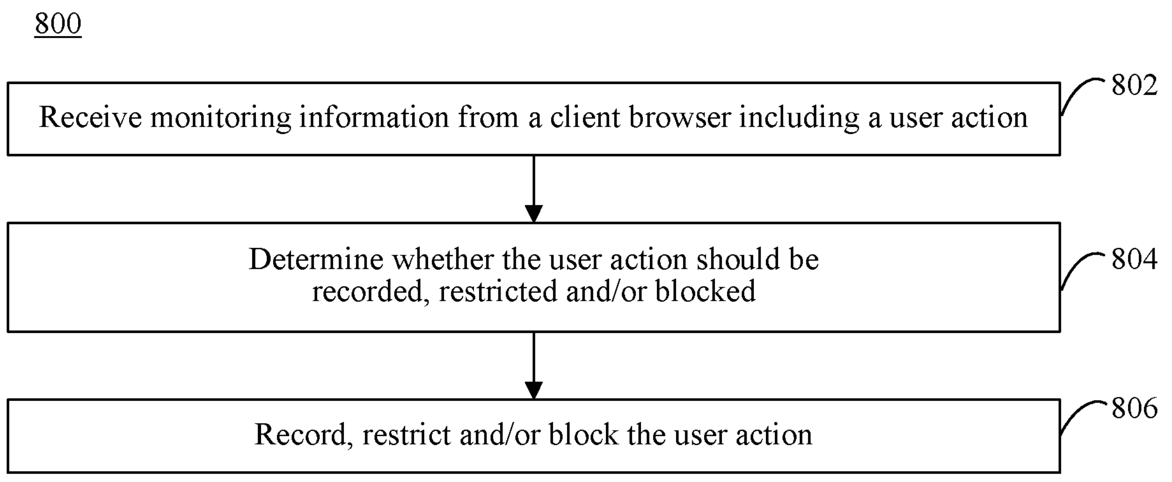
800
Receive monitoring information from a client browser including a user action
802
Determine whether the user action should be recorded, restricted and/or blocked
804
Record, restrict and/or block the user action
806

FIG. 8

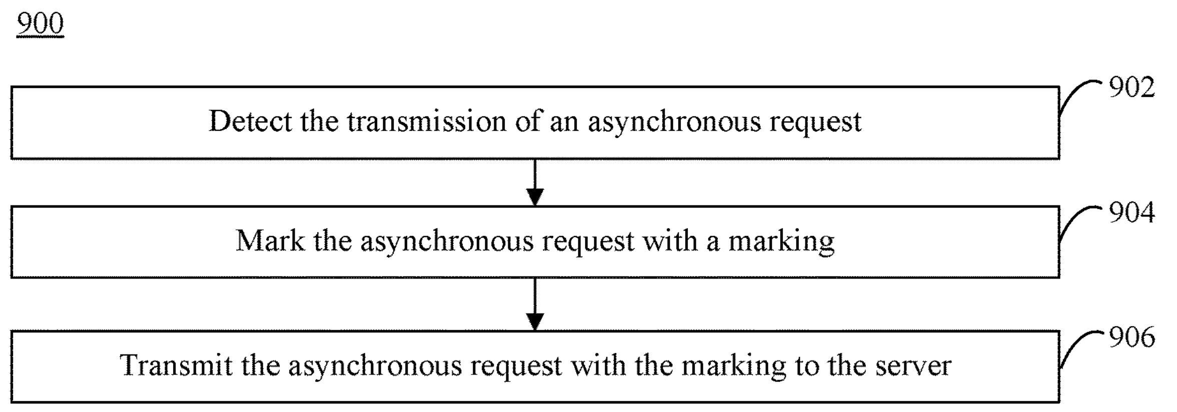
900
Detect the transmission of an asynchronous request
902
Mark the asynchronous request with a marking
904
Transmit the asynchronous request with the marking to the server
906

FIG. 9

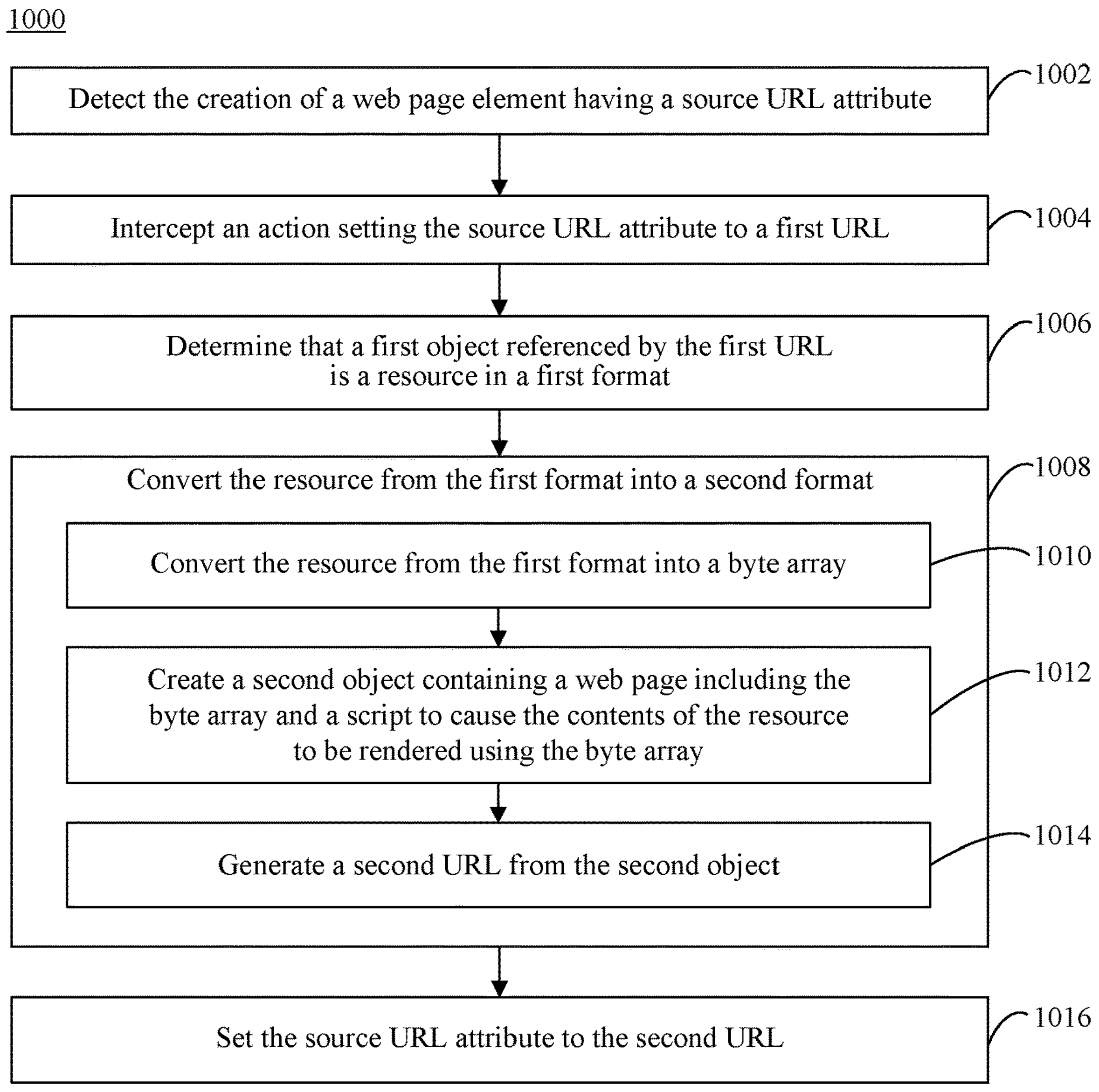
1000
Detect the creation of a web page element having a source URL attribute
1002
Intercept an action setting the source URL attribute to a first URL
1004
Determine that a first object referenced by the first URL is a resource in a first format
1006
Convert the resource from the first format into a second format
1008
Convert the resource from the first format into a byte array
1010
Create a second object containing a web page including the byte array and a script to cause the contents of the resource to be rendered using the byte array
1012
Generate a second URL from the second object
1014
Set the source URL attribute to the second URL
1016

FIG. 10

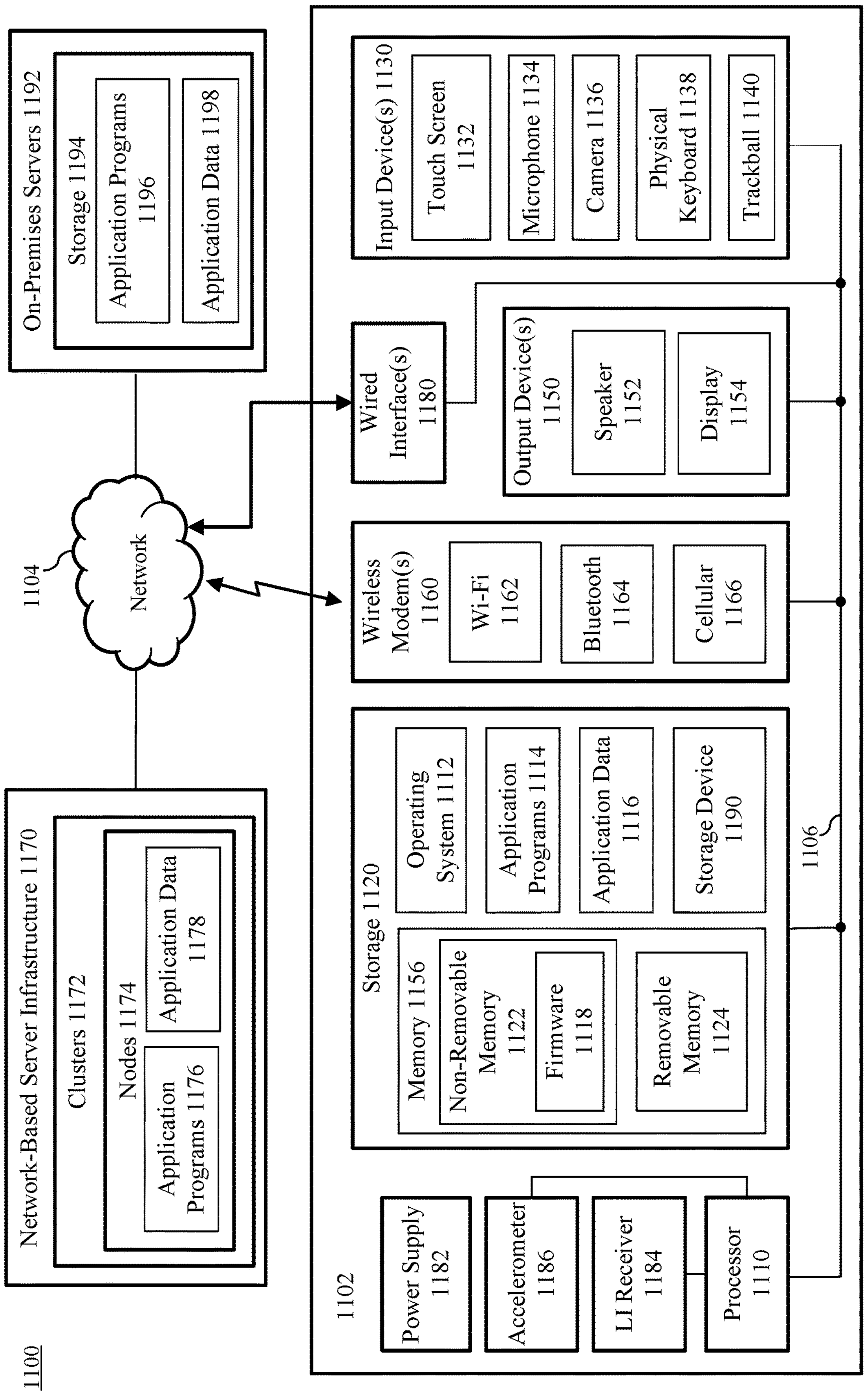
1100
Network-Based Server Infrastructure 1170
Clusters 1172
Nodes 1174
Application Programs 1176
Application Data 1178
1104
Network
On-Premises Servers 1192
Storage 1194
Application Programs 1196
Application Data 1198
1102
Power Supply 1182
Accelerometer 1186
LI Receiver 1184
Processor 1110
Storage 1120
Memory 1156
Non-Removable Memory 1122
Firmware 1118
Removable Memory 1124
Operating System 1112
Application Programs 1114
Application Data 1116
Storage Device 1190
1106
Wireless Modem(s) 1160
Wi-Fi 1162
Bluetooth 1164
Cellular 1166
Wired Interface(s) 1180
Output Device(s) 1150
Speaker 1152
Display 1154
Input Device(s) 1130
Touch Screen 1132
Microphone 1134
Camera 1136
Physical Keyboard 1138
Trackball 1140

FIG. 11

SYSTEM AND METHOD FOR MONITORING USER ACTIONS WITH RESPECT TO A RESOURCE PRESENTED BY A WEB BROWSER

BACKGROUND

A cloud access security broker (CASB) is a web proxy that sits between a web server executing on a server computing device and a web browser executing on a client computing device to monitor interactions between the two sides and enforce security policies during these interactions. For example, the web proxy may be able to intercept resource requests emanating from a web browser and, based on a series of access control protocols, manage what a user of the web browser can access and interact with in regard to a particular set of resources. Furthermore, the web proxy can collect important information about user traffic within a computing ecosystem, which can provide valuable insights for detecting, diagnosing, and remedying possible security breaches.

A conventional CASB web proxy may be configured to modify code (e.g., JavaScript code) included in a web page that it receives from a web server before it passes the web page to a web browser executing on a client computing device. For example, a web proxy may be configured to inject into a web page code that detects actions happening on the client side that should be subject to policy evaluation (e.g., a file upload or download that transpires entirely in the web browser without involvement by the web server). However, the injected code may not be able to detect client-side actions when the content is rendered by the web browser using a file viewer. For example, Chromium-based web browsers render Portable Document Format (PDF) files using a built-in PDF file viewer that limits the visibility of actions by the injected code executing on the web browser.

SUMMARY

This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter.

Systems and methods described herein enable proxy server monitoring of client-side actions with respect to resources presented by a browser using a file viewer (e.g., PDF files). The proxy server injects code into a web page requested by the web browser to monitor client-side actions with respect to the web page. The web browser, by executing the injected code, can detect the creation of a web page element having a remote source Uniform Resource Locator (URL) and mark the source URL prior to sending a request including the source URL to the proxy server. If the resource referenced by the source URL is in a first format that is normally rendered by the web browser using a file viewer that limits the monitoring of actions with respect to the resource, the proxy server converts the resource into a second format that is rendered by the client browser in a manner that permits the client browser to monitor user actions with respect to the resource on behalf of the proxy server. The proxy server then transmits to the client browser the resource in the second format for rendering thereby in lieu of the resource in the first format.

Further features and advantages of the embodiments, as well as the structure and operation of various embodiments, are described in detail below with reference to the accompanying drawings. It is noted that the claimed subject matter is not limited to the specific embodiments described herein. Such embodiments are presented herein for illustrative purposes only. Additional embodiments will be apparent to persons skilled in the relevant art(s) based on the teachings contained herein.

BRIEF DESCRIPTION OF THE DRAWINGS/FIGURES

The accompanying drawings, which are incorporated herein and form a part of the specification, illustrate embodiments of the present application and, together with the description, further serve to explain the principles of the embodiments and to enable a person skilled in the pertinent art to make and use the embodiments.

FIG. **1** shows a block diagram of an example system that enables redirection of requests directed to a web server to a proxy service, in accordance with an embodiment.

FIG. **2** depicts a block diagram of an example system in which a proxy computing device is interconnected between a client computing device and a server computing device, where the proxy computing device executes a proxy service, the client computing device executes a web browser, and the server computing device executes a web server, in accordance with an embodiment.

FIG. **3** depicts a flowchart of a process for modifying a web page, in accordance with an embodiment.

FIG. **4** depicts a flowchart of a process for monitoring a web page, in accordance with an embodiment.

FIG. **5** depicts a block diagram of an example system in which a proxy computing device is interconnected between a client computing device and a server computing device, where the proxy computing device executes a proxy service, the client computing device executes a web browser, and the server computing device executes a web server, in accordance with an embodiment.

FIG. **6** depicts a flowchart of a process for converting a resource in a first format into a second format, in accordance with an embodiment.

FIG. **7** depicts a flowchart of a process for rendering a resource using a byte array, in accordance with an embodiment.

FIG. **8** depicts a flowchart of a process for monitoring user actions with respect to a web page, in accordance with an embodiment.

FIG. **9** depicts a flowchart of a process for monitoring a web page, in accordance with an embodiment.

FIG. **10** depicts a flowchart of a process for converting a resource in a first format into a second format, in accordance with an embodiment.

FIG. **11** shows a block diagram of an example computer system in which embodiments may be implemented.

The subject matter of the present application will now be described with reference to the accompanying drawings. In the drawings, like reference numbers indicate identical or functionally similar elements. Additionally, the left-most digit(s) of a reference number identifies the drawing in which the reference number first appears.

DETAILED DESCRIPTION

I. Introduction

The following detailed description discloses numerous example embodiments. The scope of the present patent application is not limited to the disclosed embodiments, but also encompasses combinations of the disclosed embodiments, as well as modifications to the disclosed embodiments.

Numerous exemplary embodiments are now described. Any section/subsection headings provided herein are not intended to be limiting. Embodiments are described throughout this document, and any type of embodiment may be included under any section/subsection. Furthermore, embodiments disclosed in any section/subsection may be combined with any other embodiments described in the same section/subsection and/or a different section/subsection in any manner.

As discussed in the Background Section above, a CASB web proxy may be configured to inject code (e.g., JavaScript code) into a web page that it receives from a web server before it passes the web page to a web browser executing on a client computing device. When executed by the web browser, the injected code causes the web browser to monitor and detect client-side actions and to transmit information about the detected actions to a proxy service. For example, actions of interest to the proxy service may include navigation actions, file download actions, file upload actions, asynchronous JavaScript, and XML (AJAX) actions, and/or any other actions that may be executed by web browser responsive to displaying a web page and/or responsive to a user's interactions therewith. The detected actions may be used by the proxy service to carry out enforcement of user, device, network and/or content related policies.

In some cases, monitoring is hindered by the web browser's use of a file viewer. For example, Chromium-based browsers employ a built-in PDF viewer to render PDF files. Actions occurring with respect to PDF files rendered inside the built-in PDF viewer are not visible to the injected code executing on the web browser. The unavailability of monitoring information with respect to PDF files rendered by the web browser using the built-in PDF viewer limits the proxy service's ability to enforce policies on a granular level. As such, enforcement of a policy regarding PDF files would require the proxy service to completely block all PDF files. For example, a policy may allow the viewing of PDF files, but not the printing of PDF files. However, the web browser's built-in PDF viewer limits the proxy service's ability detect when a user is attempting to print a PDF file. As such, to enforce the policy, the proxy service must simply prevent all access to PDF files.

II. System Overview

Systems and methods described herein enable proxy server monitoring of client-side actions with respect to resources presented by a browser using a file viewer (e.g., PDF files). The proxy server injects code into a web page requested by the web browser to monitor client-side actions with respect to the web page. The web browser, by executing the injected code, can detect the creation of a web page element having a remote source URL and mark the source URL prior to sending a request including the source URL to the proxy server. If the resource referenced by the source URL is in a first format that is normally rendered by the web browser using a file viewer that limits the monitoring of actions with respect to the resource, the proxy server converts the resource into a second format that is rendered by the client browser in a manner that permits the client browser to monitor user actions with respect to the resource on behalf of the proxy server. The proxy server then transmits to the client browser the resource in the second format for rendering thereby in lieu of the resource in the first format. For example, the proxy server may convert the resource into a byte array, generate a new web page that that includes the byte array and additional code to cause the web browser to render the resource using the byte array, and then transmit the new web page to the web browser for rendering thereby.

To help illustrate the aforementioned systems and methods, FIG. **1** will now be described. In particular, FIG. **1** is a block diagram of an example system **100** that enables redirection of requests directed to a web server to a proxy service, in accordance with an embodiment. As shown in FIG. **1**, system **100** includes a cloud services network **102** and a client computing device **114**. As further shown in FIG. **1**, cloud services network **102** includes a server computing device **104**, an identity provider **108**, and a proxy computing device **110**. Server computing device **104** is configured to execute a web server **106**, proxy computing device **110** is configured to execute a proxy service **112**, and client computing device **114** is configured to execute a web browser **116**.

In FIG. **1**, web server **106** implements an application or service that is capable of serving resources to clients such as client computing device **114**, wherein such resources include web pages. Although web server **106** is shown as being implemented on a single server computing device **104**, in alternate embodiments web server **106** may be implemented on multiple server computing devices and/or one or more other computing devices.

Identity provider **108** is a computer-implemented system that is configured to create, maintain, and manage identity information associated with users while providing authentication services to relying web services. Identity provider **108** may be implemented, for example, on one or more server computing devices.

Proxy service **112** is a computer-implemented system that is configured to monitor and manage interactions between the application or service implemented by web server **106** and users thereof. Although proxy service **112** is shown as being implemented on a single proxy computing device **110**, in alternate embodiments proxy service **112** may be implemented on multiple proxy computing devices and/or one or more other computing devices.

Each component of cloud services network **102** and client computing device **114** may be communicatively connected via one or more networks (not pictured in FIG. **1**). These one or more networks may include, for example and without limitation, one or more of a local area network (LAN), a wide area network (WAN), a personal area network (PAN), a private network, a public network, a packet network, a circuit-switched network, a wired network and/or a wireless network.

Client computing device **114** may be any type of computing device, including a stationary or mobile computing device. Examples of a stationary computing device include but are not limited to a desktop computer, a personal computer (PC), a video game console, or a smart appliance (e.g., a smart television). Examples of a mobile computing device include but are not limited to a smart phone, a laptop computer, a notebook computer, a tablet computer, a netbook, or a wearable computing device (e.g., a smart watch, a head-mounted device including smart glasses such as Google® Glass™, etc.)

As depicted in FIG. **1**, web browser **116** of client computing device **114** may submit a request to web server **106** of server computing device **104** that requests a resource thereof. The request may be submitted, for example, on behalf of a user of client computing device **114**.

In response to receiving request **120**, web server **106** may determine that the user has not yet been authenticated and may therefore provide a response **122** to web browser **116** that causes web browser **116** to send a request **124** to identity provider **108** for user authentication. For instance, web server **106** may redirect web browser **116** to identity provider **108** in response to determining that a required authentication artifact (e.g., a token) was not provided with request **120**.

After receiving request **124**, identity provider **108** may determine based on an access policy whether web browser **116** should access the resource via proxy service **112**. An access policy may specify that network cloud traffic associated with certain users, certain groups of users, and/or certain web services should be routed to proxy service **112** for monitoring and/or management. In embodiments, an information technology (IT) administrator for an organization may set access policies for applications and users of client computing devices that access a computer network of the organization. For example, identity provider **108** may evaluate a user's login (e.g., username and password) and determine that there is a policy associated with that user that indicates that the user should access the resource via proxy service **112**.

Identity provider **108** may further authenticate the user associated with request **124** and create an authentication artifact (e.g., a token) that can be used by web server **106** to determine whether the user should be granted access to the resource. In some embodiments, during authentication, a user may be prompted by identity provider **108** to provide his or her user login credentials. After determining that web browser **116** should access the resource via proxy service **112**, identity provider **108** may send a response **126** to web browser **116** that includes an encrypted version of the authentication artifact and that redirects web browser **116** to send a request **128** to proxy service **112** that includes such encrypted authentication artifact.

After receiving redirected request **128**, proxy service **112** may decrypt the authentication artifact and then generate a corresponding request **130** that includes the decrypted authentication artifact and provide it to web server **106**. Web server **106** may grant or deny access to the resource based on the authentication artifact. If access is granted, web server **106** may interpret request **130**, generate a response **132** to request **130**, and issue response **132** to proxy service **112**. In some embodiments, response **132** may include a file stored on web server **106** or an output from a program executing on web server **106**. In other embodiments, response **132** may include an error message if the request could not be fulfilled.

After receiving response **132**, proxy service **112** may generate a response **134** (e.g., a response that includes a web page) and send it to web browser **116**. In response to receiving response **134**, web browser **116** may interpret response **134** and display contents of response **134** (e.g., when response **134** includes a web page) within a window of web browser **116** for the user of client computing device **114**. Response **134** may be the same as response **132** or a response modified by proxy service **112** (as discussed in greater detail herein). Any further requests related to accessing a resource of web server **106** and originating in web browser **116** during the user's proxy session may be directed to proxy service **112**, and any responses generated by proxy service **112** to the further requests may be issued to web browser **116** by proxy service **112** on behalf of web server **106**.

In some embodiments, proxy service **112** may be configured to act as a suffix proxy. Suffix proxies enable a user to access content via a proxy server by appending the name of the proxy server to a domain URL of the requested content. For example, if a web page identifies a content source using the domain URL "targetapplication.com", proxy service **112** may rename the domain URL such that it instead appears as domain URL "targetapplication.com.proxyserver".

To help further illustrate the features of proxy service **112** in accordance with embodiments, FIG. **2** will now be described. In particular, FIG. **2** is a block diagram of an example system **200** in which a proxy computing device is interconnected between a client computing device and a server computing device, where the proxy computing device executes a proxy service, the client computing device executes a web browser, and the server computing device executes a web server, in accordance with an embodiment. As shown in FIG. **2**, system **200** includes: client computing device **114**, proxy computing device **110**, and server computing device **104**, as described above with respect to FIG. **1**. As further shown in FIG. **2**, proxy computing device **110** includes proxy service **112**, as described in FIG. **1**, which includes a web page modifier **210**, and a code injector **212**. Web page modifier **210** receives a first web page **206**. Code injector **212**, which may optionally include code **214**, injects code **214** into first web page **206** to generate a modified first web page **216**. Web page modifier **210** outputs the modified first web page **216** for transmission to web browser **116** on client computing device **114**. First web page **206** includes contents **208** while modified first web page **216** includes contents **208** along with code **214**, as described further below.

As discussed above in reference to FIG. **1**, proxy computing device **110** is communicatively interconnected between client computing device **114** and server computing device **104** via one or more networks (not pictured in FIG. **2**). Proxy computing device **110** may establish itself as an intermediary for client computing device **114** and server computing device **104** in accordance with the process described above in reference to FIG. **1**.

Proxy service **112** running on proxy computing device **110** may be configured to manage messages (e.g., requests and/or responses) sent between web browser **116** and web server **106**. For example, proxy service **112** receives request **202** sent from web browser **116**. In an embodiment, proxy service **112** may receive request **202** responsive to an identity provider having determined based on an access policy that requests from a user should be redirected to proxy service **112**. For example, the identity provider may identify an access policy associated with a user of client computing device **114** and/or a policy associated with an application or service that the user is trying to access that indicates that interactions between the user and the application or service should be conducted via proxy service **112**. As such, any requests sent from web browser **116** to web server **106** will be redirected to proxy service **112** during the user's active proxy session.

Web page modifier **210** of proxy service **112** may be configured to modify messages sent between web server **106** and web browser **116**. For example, in response to receiving request **202** from web browser **116**, proxy service **112** may issue a corresponding request **204** to web server **106**, requesting that web server **106** fulfill request **202**. Proxy service **112** then receives a response corresponding to request **204** from web server **106** that includes first web page **206**. After receiving the response including first web page **206**, web page modifier **210** may modify first web page **206** and send a response including a modified first web page **216** to web browser **116**.

Code injector **212** of proxy service **112** may be configured to inject code **214** (e.g., JavaScript code) into first web page **206**. Code **214**, when executed by web browser **116**, may cause web browser **116** to monitor actions of interest to proxy service **112**, such as navigation actions, file download actions, file upload actions, asynchronous JavaScript and XML (AJAX) actions, and/or any other actions that may be executed by web browser **116** of client computing device **114** responsive to displaying modified first web page **216** and/or responsive to a user's interactions therewith.

To further illustrate the foregoing features of proxy service **112**, FIG. **3** is described. FIG. **3** depicts a flowchart **300** of a process for modifying a web page, in accordance with an embodiment. Proxy computing device **110** may operate according to flowchart **300** in embodiments. Note that not all steps of flowchart **300** need be performed in embodiments. Further structural and operational embodiments will be apparent to persons skilled in the relevant art(s) based on the following description of FIG. **3**. FIG. **3** is described as follows with reference to system **200** of FIG. **2**.

Flowchart **300** begins at step **302**. In step **302**, a request is received for a first web page from a client browser. For instance, proxy service **112**, running on proxy computing device **110** may receive a request **202** from web browser **116** of computing device **104**.

In step **304**, the request is transmitted to a server. For instance, proxy service **112** on proxy computing device **110** may transmit request **204** to web server **106** on server computing device **104**. In some embodiments, request **202** is transmitted unchanged, as request **204**, to web server **106**. In other embodiments, proxy service **112** may modify request **202** to form request **204**.

In step **306**, a first web page is received from the server. For instance, proxy service **112** running on proxy computing device **110** may receive first web page **206** from web server **106** of server computing device **104**. First web page **206** may be received in response to proxy service **112** having sent request **204**, although this is only an example. First web page **206** includes contents **208**. In some embodiments, first web page **206** may also include, or link to, code (not shown) (e.g., JavaScript code) for providing dynamic content with respect to first web page **206**.

In step **308**, code is injected into the first web page to form a modified first web page. For instance, web page modifier **210**, in conjunction with code injector **212**, may inject code **214** into first web page **206** to generate modified first web page **216**.

In step **310**, the modified first web page is transmitted to the client browser. For instance, proxy service **112** running on proxy computing device **110** may transmit modified first web page **216** including injected code **214** to web browser **116** on client computing device **114**. Code **214**, when executed by web browser **116**, may cause web browser **116** to monitor actions of interest to proxy service **112**, such as navigation actions, file download actions, file upload actions, asynchronous Javascript and XML (AJAX) actions, and/or any other actions that may be executed by web browser **116** of client computing device **114** responsive to displaying modified first web page **216** and/or responsive to a user's interactions therewith.

III. Proxy-Side Conversion

Systems and methods described herein enable proxy server monitoring of client-side actions with respect to resources presented by a browser using a file viewer (e.g., PDF files). The proxy server injects code into a web page requested by the web browser to cause the web browser to mark a URL of an element that is created by the web page. If the proxy server encounters a request containing the marked URL, the proxy server examines the corresponding response to determine if the response includes a resource in a first format that is normally rendered by the web browser using a file viewer. If the response includes a resource in the first format, the proxy server converts the resource into a second format that is rendered by the client browser in a manner that permits the client browser to monitor user actions with respect to the resource on behalf of the proxy server. The proxy server then transmits to the client browser the resource in the second format for rendering thereby in lieu of the resource in the first format. For example, the proxy server may convert the resource into a byte array, generate a new web page that includes the byte array and additional code to cause the web browser to render the resource using the byte array, and then transmit the new web page to the web browser for rendering thereby.

To further illustrate the foregoing features of web browser **116**, FIG. **4** is described. FIG. **4** depicts a flowchart **400** of a process for monitoring a web page, in accordance with an embodiment. Client computing device **114** may operate according to flowchart **400** in embodiments. Note that not all steps of flowchart **400** need be performed in embodiments. Further structural and operational embodiments will be apparent to persons skilled in the relevant art(s) based on the following description of FIG. **4**. FIG. **4** is described as follows with reference to system **200** of FIG. **2**.

Flowchart **400** begins at step **402**. In step **402**, a modified first web page is monitored using injected code. For instance, web browser **116** on client device **114** may execute injected code **214** in modified first web page **216** to monitor elements of modified first web page **216**.

In step **404**, the creation of an element of the web page having a source attribute that is a remote URL is detected. In embodiments described herein, code **214**, when executed by web browser **116**, may additionally cause web browser **116** to monitor and detect the creation of elements by web page **216** that include a source attribute that is a remote URL. For instance, web browser **116** on client device **114** may execute injected code **214** in modified first web page **216** to detect the creation of elements of modified web page **216** that have a source attribute that is a remote URL. Such elements may include a source (e.g., 'src') attribute that references a remote resource. Examples of such web page elements may include, but are not limited to, <iframe>, <object> and <embed> elements.

In step **406**, the URL is marked with a marking. For instance, web browser **116** on client device **114** may execute injected code **214** in modified first web page **216** to mark the URL in the source attribute of the detected element with a marking. In some embodiments, web browser **116** may mark the URL by appending the marking to the URL in the source attribute of the detected element. In other embodiments, web browser **116** may mark the URL by modifying the URL in the source attribute of the detected element.

In step **408**, a first request containing the URL and the marking is transmitted. For instance, when web browser **116** processes the detected element with the marked URL, web browser **116** may transmit a first request for the resource referenced by the marked URL to proxy service **112** on proxy computing device **110**.

To help further illustrate the features of proxy service **112** in accordance with embodiments, FIG. **5** will now be described. In particular, FIG. **5** is a block diagram of an example system **500** in which a proxy computing device is interconnected between a client computing device and a server computing device, where the proxy computing device executes a proxy service, the client computing device executes a web browser, and the server computing device executes a web server, in accordance with an embodiment. As shown in FIG. **5**, system **500** includes: client computing device **114**, proxy computing device **110**, and server computing device **104**, as described above with respect to FIG. **1**. As further shown in FIG. **5**, proxy computing device **110** includes proxy service **112**, as described in FIG. **1**, which includes a request rewriter **504**, a response analyzer **512**, and a resource converter **514**. Resource converter **514** may further include a web page generator **518**.

Request rewriter **504** receives a first request **502** and determines whether the request includes a marked URL. If first request **502** includes a marked URL, request rewriter **504** extracts the marking from the marked URL to form a second request **506**. Request rewriter **504** then transmits second request **506** to web server **106** on server computing device **104**. Request rewriter **504** may optionally flag or otherwise inform response analyzer **512** that second request **506** corresponds to a request that included a marked URL (i.e., first request **502**). Response analyzer **512** receives a response from web server **106** on server computing device **104**, wherein the response includes a resource **508** that includes contents **510**. Resource **508** may be a file (e.g., a PDF file) or any other type of web content (e.g., a web page).

Response analyzer **512** analyzes the response to determine if the response corresponds to a request that included a marked URL. If the response corresponds to a request that included a marked URL, response analyzer **512** analyzes resource **508** and/or contents **510** to determine whether resource **508** and/or contents **510** is a type that is handled by web browser **116** using a file viewer that limits the monitoring of actions with respect to the resource. In some embodiments, the content type may be determined by analyzing "content-type" field(s) in the header of the response, in resource **508**, and/or in contents **510**.

When the resource is a type that is handled by web browser **116** using a file viewer that limits the monitoring of actions with respect to the resource, resource converter **514** converts resource **508** and/or contents **510** into a byte array **516** (e.g., converts a PDF document into a byte array). Web page generator **518** may then generate a second web page **520** that includes code **522** and byte array **516**. Code **522**, when executed by web browser **116**, will cause web browser **116** to render the contents **510** of resource **508** using byte array **516**. In some embodiments, code **522** may additionally include, or link to, library **524**. Library **524** includes code that is used to render the contents of the byte array using web page elements. In some embodiments, library **524** may render the contents onto an HTML5 <canvas> element using canvas drawing commands. Web page generator **518** may output second web page **520** for transmission to web browser **116** on client computing device **114**.

To further illustrate the foregoing features of proxy service **112**, FIG. **6** is described. FIG. **6** depicts a flowchart **600** of a process for converting a resource in a first format into a second format, in accordance with an embodiment. Proxy computing device **110** may operate according to flowchart **600** in embodiments. Note that not all steps of flowchart **600** need be performed in embodiments. Further structural and operational embodiments will be apparent to persons skilled in the relevant art(s) based on the following description of FIG. **6**. FIG. **6** is described as follows with reference to system **500** of FIG. **5**.

Flowchart **600** begins at step **602**. In step **602**, a first request including a URL and a marking is received. For instance, proxy service **112** on proxy computing device **110** may receive a first request **502** from web browser **116** on client computing device **114** that includes a URL and a marking.

In step **604**, the marking is extracted from the first request to form a second request. For instance, request rewriter **504** may extract the marking from first request **502** to form second request **506**.

In step **606**, the second request is transmitted to the server. For instance, proxy service **112** may transmit second request **506** to web server **106** on web computing device **104**.

In step **608**, a response is received from the server. For instance, proxy service **112** on proxy computing device **110** may receive a response from web server **106** on web computing device **104**. The response may include resource **508** that includes contents **510**.

In step **610**, it is determined whether the response corresponds to the second request. For instance, response analyzer **512** may analyze the response to determine whether it is the response to second request **506**. In some embodiments, request rewriter **504** may flag or otherwise inform response analyzer **512** that second request **506** corresponds to a request that included a marked URL (i.e., first request **502**). This information may aid response analyzer in determining whether it needs to further analyze resource **508** and/or contents **510**.

In step **612**, it is determined whether the response includes a resource that is in a first format. For instance, response analyzer **512** may analyze the response, resource **508** and/or contents **510** to determine whether the response includes a resource having content that is a type that is handled by web browser **116** using a file viewer that limits the monitoring of actions with respect to the resource. In some embodiments, the content type may be determined by analyzing "content-type" field(s) in the header of the response, in resource **508**, and/or in content **510**. In one embodiment, the first format is a PDF format and resource **508** is a PDF file.

In step **614**, the resource is converted from the first format into a second format. For instance, resource converter **514** may convert resource **508** and/or contents **510** into a second format. Step **614** may be performed by performing steps **616** and **618**.

In step **616**, the resource is converted from the first format into a byte array. For instance, resource converter **514** may convert resource **508** and/or contents **510** into a byte array **516**.

In step **618**, a second web page including the byte array and a script is generated, the script to cause the contents of the resource to be rendered using the byte array. For instance, web page generator **518** may generate a second web page **520** that includes code **522** and byte array **516**. Code **522** may be a script (e.g., JavaScript) that, when executed by browser **116** on client computing device **114**, causes browser **116** to render resource **508** and/or contents **510** using byte array **516**. In some embodiments, code **522** may additionally include, or link to, library **524**. Library **524** includes code that is used to render the contents of the byte array using web page elements. In some embodiments, Library **524** may render the contents onto an HTML5 <canvas> element using canvas drawing commands.

In step **620**, the resource is transmitted to the client browser in the second format. For instance, proxy service

112 on proxy computing device **110** may transmit the second web page **520** containing code **522** and byte array **516** to web browser **116** on client computing device **114**.

To further illustrate the foregoing features of web browser **116**, FIG. **7** is described. FIG. **7** depicts a flowchart **700** of a process for rendering a resource using a byte array, in accordance with an embodiment. Client computing device **114** may operate according to flowchart **700** in embodiments. Note that not all steps of flowchart **700** need be performed in embodiments. Further structural and operational embodiments will be apparent to persons skilled in the relevant art(s) based on the following description of FIG. **7**. FIG. **7** is described as follows with reference to system **200** of FIG. **2** and **500** of FIG. **5**.

Flowchart **700** begins at step **702**. In step **702**, a second web page including a byte array is received. For instance, web browser **116** on client computing device **114** receives, in response to first request **502**, a second web page **520** that includes code **522** and byte array **516**.

In step **704**, a script in the second web page is executed to render the contents of the resource using the byte array. For instance, web browser **116** on client computing device **114** executes code **522** in the second web page **520** to render resource **508** and/or contents **510** using byte array **516**. Code **522** may be a script (e.g., JavaScript) that, when executed by browser **116** on client computing device **114**, causes browser **116** to render resource **508** and/or contents **510** using byte array **516**. In some embodiments, code **522** may additionally include, or link to, library **524**. Library **524** includes code that is used to render the contents of the byte array using web page elements. In some embodiments, library **524** may render the contents onto an HTML5 <canvas> element using canvas drawing commands. Because the resource is formatted as a byte array, web browser **116** on client computing device **114** does not recognize the resource as a type of resource that should be rendered using a file viewer.

In step **706**, user actions with respect to the content of the resource are monitored. For instance, web browser **116** on client computing device **114** may execute injected code **214** to monitor actions occurring on the client-side. When resource **508** and/or contents **510** are rendered using code **522** and/or library **524**, without using a file viewer, user actions with respect to resource **508** and/or contents **510** are visible to the injected code **214** executing on web browser **116**. User actions that may be monitored with respect to resource **508** and/or contents **510** include, but are not limited to, clipboard actions (e.g., copy, cut and/or paste), editing actions, saving actions, downloading actions, printing actions, and/or screen capture actions.

To further illustrate the foregoing features of proxy service **112**, FIG. **8** is described. FIG. **8** depicts a flowchart **800** of a process for monitoring user actions with respect to a web page, in accordance with an embodiment. Proxy computing device **110** may operate according to flowchart **800** in embodiments. Note that not all steps of flowchart **800** need be performed in embodiments. Further structural and operational embodiments will be apparent to persons skilled in the relevant art(s) based on the following description of FIG. **8**. FIG. **8** is described as follows with reference to system **200** of FIG. **2** and **500** of FIG. **5**.

Flowchart **800** begins at step **802**. In step **802**, monitoring information including a user action is received from a client browser. For instance, proxy service **112** on proxy computing device **110** receives monitoring information from web browser **116** on client computing device **114**. In some embodiments, injected code **214** and/or code **522**, when executed by web browser **116**, may cause web browser **116** to monitor client-side actions for user actions. When user actions are detected of interest are detected, web browser **116** transmits monitoring information identifying the user action to proxy service **112** on proxy computing device **110**.

In step **804**, it is determined whether the user action should be recorded, restricted and/or blocked. For instance, proxy service **112** on proxy computing device **110** may determine whether the user action should be recorded, restricted and/or blocked based on enforcement policies.

In step **806**, the user action is recorded, restricted and/or blocked. For instance, proxy service **112** on proxy computing device **110** may, based on enforcement policies, record the user actions. A record of user actions may be useful for audit purposes or for learning user behavior to fine tune the enforcement policies. User actions may also be restricted and/or blocked. For example, a user action may be intercepted by proxy service **112** or proxy service **112** may cause the web browser to restrict, block, or simply ignore, the user action. User actions that may be recorded, restricted and/or blocked include, but are not limited to include, but are not limited to, clipboard actions (e.g., copy, cut and/or paste), editing actions, saving actions, downloading actions, printing actions, and/or screen capture actions.

IV. Client-Side Conversion

Systems and methods described herein enable proxy server monitoring of client-side actions with respect to PDF files. The proxy server injects code into a web page requested by the web browser to cause the web browser to monitor the web page for asynchronous requests. If the web browser detects, by executing the injected code, an asynchronous request, it marks the request to indicate to the proxy server to ignore the body of the response corresponding to the request. When the web browser receives a response, the web browser examines, by executing the injected code, the response to determine if the response includes a resource in a first format that is normally rendered by the web browser using a file viewer that limits monitoring of actions with respect to the resource. If the response includes a resource in the first format, the web browser, by executing the injected code, converts the resource into a second format that permits the monitoring of actions with respect to the resource. For example, the web browser, by executing the injected code, may convert the resource into a byte array and generate a new web page that includes the byte array and additional code to cause the web browser to render the resource using the byte array.

To further illustrate the foregoing features of web browser **116**, FIG. **9** is described. FIG. **9** depicts a flowchart **900** of a process for rendering a resource using a byte array, in accordance with an embodiment. Client computing device **114** may operate according to flowchart **900** in embodiments. Note that not all steps of flowchart **900** need be performed in embodiments. Further structural and operational embodiments will be apparent to persons skilled in the relevant art(s) based on the following description of FIG. **9**. FIG. **9** is described as follows with reference to system **200** of FIG. **2**.

Flowchart **900** begins at step **902**. In step **902**, the transmission of an asynchronous request is detected. For instance, web browser **116** on client computing device **114**, by executing injected code **214**, may monitor and detect the transmission of an asynchronous request. An asynchronous request may include, but is not limited to, XMLHttpRequests (XHR) and/or fetch API requests.

In step **904**, the asynchronous request is marked with a marking. For instance, web browser **116** on client computing device **114**, by executing injected code **214**, may mark the detected asynchronous request with a marking to indicate to the proxy server to ignore the body of the response corresponding to the request.

In step **906**, the asynchronous request with the marking is transmitted to the server. For instance, web browser **116** on client computing device **114**, by executing injected code **214**, may transmit the detected asynchronous request along with the marking to proxy service **112** on proxy computing device **110**.

To further illustrate the foregoing features of web browser **116**, FIG. **10** is described. FIG. **10** depicts a flowchart **1000** of a process for rendering a resource using a byte array, in accordance with an embodiment. Client computing device **114** may operate according to flowchart **1000** in embodiments. Note that not all steps of flowchart **1000** need be performed in embodiments. Further structural and operational embodiments will be apparent to persons skilled in the relevant art(s) based on the following description of FIG. **10**. FIG. **10** is described as follows with reference to system **200** of FIG. **2**.

Flowchart **1000** begins at step **1002**. In step **1002**, the creation of a web page element having a source URL attribute is detected. For instance, web browser **116** on client computing device **114**, by executing injected code **214**, may detect the creation of a web page element that includes a source URL attribute. Such elements may include a source (e.g., 'src') attribute that references a remote resource. Examples of such web page elements may include, but are not limited to, <iframe>, <object> and <embed> elements.

In step **1004**, an action setting the source URL of attribute to a first URL is intercepted. For instance, web browser **116** on client computing device **114**, by executing injected code **214**, may intercept an action by the modified first web page **216** to set the source URL attribute of the detected web page element.

In step **1006**, it is determined that a first object referenced by the first URL is a resource in a first format. For instance, web browser **116** on client computing device **114**, by executing injected code **214**, may analyze the contents of the first object referenced by the first URL to determine whether the first object includes a resource having content that is a type that is handled by web browser **116** using a file viewer that limits the monitoring of actions with respect to the resource. In some embodiments, the content type may be determined by analyzing "content-type" field(s) in the first object.

In step **1008**, the resource is converted from the first format into a second format. For instance, web browser **116** on client computing device **114**, by executing injected code **214**, may convert the first object into a resource having a second format. Step **1008** may be performed by performing steps **1010**, **1012** and/or **1014**.

In step **1010**, the resource is converted from the first format into a byte array. For instance, web browser **116** on client computing device **114**, by executing injected code **214**, may convert the first object into a byte array.

In step **1012**, a second object containing a web page including the byte array and a script is generated, the script to cause the contents of the resource to be rendered using the byte array. For instance, web browser **116** on client computing device **114**, by executing injected code **214**, may generate a second object including a web page that includes a script and the byte array. The script (e.g., JavaScript), when executed by browser **116** on client computing device **114**, causes browser **116** to render the contents of the first object using the byte array. In some embodiments, the script may additionally include, or link to, library that is used to render the contents of the byte array using web page elements. In some embodiments, the library may render the contents onto an HTML5<canvas> element using canvas drawing commands.

In step **1014**, a second URL is generated from the second object. For instance, web browser **116** on client computing device **114**, by executing injected code **214**, may generate a second URL that references the second object. The second URL may be a local URL that references the second object that is stored locally on client computing device **114**.

In step **1016**, the source URL attribute is set to the second URL. For instance, web browser **116** on client computing device **114**, by executing injected code **214**, may set the URL attribute of the detected web page element to the second URL instead of the first URL. This causes web browser **116** to render the contents of the resource using the web page in the second object referenced by the second URL instead of the first object referenced by the first URL. Because the resource is formatted as a byte array, web browser **116** on client computing device **114** does not recognize the resource as a type of resource that should be rendered using a file viewer.

V. Example Mobile Device and Computer System Implementation

The systems and methods described above in reference to FIGS. **1-10**, including cloud services network **102**, server computing device **104**, web server **106**, identity provider **108**, proxy computing device **110**, proxy service **112**, client computing device **114**, web browser **116**, web page modifier **210**, code injector **212**, request rewriter **504**, response analyzer **512**, resource converter **514**, web page generator **518**, and/or each of the components described therein, and the steps of flowcharts **300**, **400**, **600**, **700**, **800**, **900** and **1000** may be implemented in hardware, or hardware combined with one or both of software and/or firmware. For example, cloud services network **102**, server computing device **104**, web server **106**, identity provider **108**, proxy computing device **110**, proxy service **112**, client computing device **114**, web browser **116**, web page modifier **210**, code injector **212**, request rewriter **504**, response analyzer **512**, resource converter **514**, web page generator **518**, and/or each of the components described therein, and the steps of flowcharts **300**, **400**, **600**, **700**, **800**, **900** and **1000** may be each implemented as computer program code/instructions configured to be executed in one or more processors and stored in a computer readable storage medium. Alternatively, cloud services network **102**, server computing device **104**, web server **106**, identity provider **108**, proxy computing device **110**, proxy service **112**, client computing device **114**, web browser **116**, web page modifier **210**, code injector **212**, request rewriter **504**, response analyzer **512**, resource converter **514**, web page generator **518**, and/or each of the components described therein, and steps of flowcharts **300**, **400**, **600**, **700**, **800**, **900** and **1000** may be each implemented in one or more SoCs (system on chip). An SoC may include an integrated circuit chip that includes one or more of a processor (e.g., a central processing unit (CPU), microcontroller, microprocessor, digital signal processor (DSP), etc.), memory, one or more communication interfaces, and/or further circuits, and may optionally execute received program code and/or include embedded firmware to perform functions.

Embodiments disclosed herein may be implemented in one or more computing devices that may be mobile (a mobile device) and/or stationary (a stationary device) and may include any combination of the features of such mobile and stationary computing devices. Examples of computing devices, such as system **100** of FIG. **1**, in which embodiments may be implemented are described as follows with respect to FIG. **11**. FIG. **11** shows a block diagram of an exemplary computing environment **1100** that includes a computing device **1102**. In some embodiments, computing device **1102** is communicatively coupled with devices (not shown in FIG. **11**) external to computing environment **1100** via network **1104**. Network **1104** comprises one or more networks such as local area networks (LANs), wide area networks (WANs), enterprise networks, the Internet, etc., and may include one or more wired and/or wireless portions. Network **1104** may additionally or alternatively include a cellular network for cellular communications. Computing device **1102** is described in detail as follows

Computing device **1102** can be any of a variety of types of computing devices. For example, computing device **1102** may be a mobile computing device such as a handheld computer (e.g., a personal digital assistant (PDA)), a laptop computer, a tablet computer (such as an Apple iPad™), a hybrid device, a notebook computer (e.g., a Google Chromebook™ by Google LLC), a netbook, a mobile phone (e.g., a cell phone, a smart phone such as an Apple® iPhone® by Apple Inc., a phone implementing the Google® Android™ operating system, etc.), a wearable computing device (e.g., a head-mounted augmented reality and/or virtual reality device including smart glasses such as Google® Glass™, Oculus Rift® of Facebook Technologies, LLC, etc.), or other type of mobile computing device. Computing device **1102** may alternatively be a stationary computing device such as a desktop computer, a personal computer (PC), a stationary server device, a minicomputer, a mainframe, a supercomputer, etc.

As shown in FIG. **11**, computing device **1102** includes a variety of hardware and software components, including a processor **1110**, a storage **1120**, one or more input devices **1130**, one or more output devices **1150**, one or more wireless modems **1160**, one or more wired interfaces **1180**, a power supply **1182**, a location information (LI) receiver **1184**, and an accelerometer **1186**. Storage **1120** includes memory **1156**, which includes non-removable memory **1122** and removable memory **1124**, and a storage device **1190**. Storage **1120** also stores an operating system **1112**, application programs **1114**, and application data **1116**. Wireless modem(s) **1160** include a WI-FI modem **1162**, a BLUETOOTH modem **1164**, and a cellular modem **1166**. Output device(s) **1150** includes a speaker **1152** and a display **1154**. Input device(s) **1130** includes a touch screen **1132**, a microphone **1134**, a camera **1136**, a physical keyboard **1138**, and a trackball **1140**. Not all components of computing device **1102** shown in FIG. **11** are present in all embodiments, additional components not shown may be present, and any combination of the components may be present in a particular embodiment. These components of computing device **1102** are described as follows.

A single processor **1110** (e.g., central processing unit (CPU), microcontroller, a microprocessor, signal processor, ASIC (application specific integrated circuit), and/or other physical hardware processor circuit) or multiple processors **1110** may be present in computing device **1102** for performing such tasks as program execution, signal coding, data processing, input/output processing, power control, and/or other functions. Processor **1110** may be a single-core or

multi-core processor, and each processor core may be single-threaded or multithreaded (to provide multiple threads of execution concurrently). Processor **1110** is configured to execute program code stored in a computer readable medium, such as program code of operating system **1112** and application programs **1114** stored in storage **1120**. Operating system **1112** controls the allocation and usage of the components of computing device **1102** and provides support for one or more application programs **1114** (also referred to as "applications" or "apps"). Application programs **1114** may include common computing applications (e.g., e-mail applications, calendars, contact managers, web browsers, messaging applications), further computing applications (e.g., word processing applications, mapping applications, media player applications, productivity suite applications), one or more machine learning (ML) models, as well as applications related to the embodiments disclosed elsewhere herein.

Any component in computing device **1102** can communicate with any other component according to function, although not all connections are shown for case of illustration. For instance, as shown in FIG. **11**, bus **1106** is a multiple signal line communication medium (e.g., conductive traces in silicon, metal traces along a motherboard, wires, etc.) that may be present to communicatively couple processor **1110** to various other components of computing device **1102**, although in other embodiments, an alternative bus, further buses, and/or one or more individual signal lines may be present to communicatively couple components. Bus **1106** represents one or more of any of several types of bus structures, including a memory bus or memory controller, a peripheral bus, an accelerated graphics port, and a processor or local bus using any of a variety of bus architectures.

Storage **1120** is physical storage that includes one or both of memory **1156** and storage device **1190**, which store operating system **1112**, application programs **1114**, and application data **1116** according to any distribution. Non-removable memory **1122** includes one or more of RAM (random access memory), ROM (read only memory), flash memory, a solid-state drive (SSD), a hard disk drive (e.g., a disk drive for reading from and writing to a hard disk), and/or other physical memory device type. Non-removable memory **1122** may include main memory and may be separate from or fabricated in a same integrated circuit as processor **1110**. As shown in FIG. **11**, non-removable memory **1122** stores firmware **1118**, which may be present to provide low-level control of hardware. Examples of firmware **1118** include BIOS (Basic Input/Output System, such as on personal computers) and boot firmware (e.g., on smart phones). Removable memory **1124** may be inserted into a receptacle of or otherwise coupled to computing device **1102** and can be removed by a user from computing device **1102**. Removable memory **1124** can include any suitable removable memory device type, including an SD (Secure Digital) card, a Subscriber Identity Module (SIM) card, which is well known in GSM (Global System for Mobile Communications) communication systems, and/or other removable physical memory device type. One or more of storage device **1190** may be present that are internal and/or external to a housing of computing device **1102** and may or may not be removable. Examples of storage device **1190** include a hard disk drive, a SSD, a thumb drive (e.g., a USB (Universal Serial Bus) flash drive), or other physical storage device.

One or more programs may be stored in storage **1120**. Such programs include operating system **1112**, one or more application programs **1114**, and other program modules and program data. Examples of such application programs may include, for example, computer program logic (e.g., computer program code/instructions) for implementing one or more of cloud services network **102**, server computing device **104**, web server **106**, identity provider **108**, proxy computing device **110**, proxy service **112**, client computing device **114**, web browser **116**, web page modifier **210**, code injector **212**, request rewriter **504**, response analyzer **512**, resource converter **514**, web page generator **518**, and/or each of the components described therein, along with any components and/or subcomponents thereof, as well as the flowcharts/flow diagrams (e.g., flowcharts **300**, **400**, **600**, **700**, **800**, **900** and/or **1000**) described herein, including portions thereof, and/or further examples described herein.

Storage **1120** also stores data used and/or generated by operating system **1112** and application programs **1114** as application data **1116**. Examples of application data **1116** include web pages, text, images, tables, sound files, video data, and other data, which may also be sent to and/or received from one or more network servers or other devices via one or more wired or wireless networks. Storage **1120** can be used to store further data including a subscriber identifier, such as an International Mobile Subscriber Identity (IMSI), and an equipment identifier, such as an International Mobile Equipment Identifier (IMEI). Such identifiers can be transmitted to a network server to identify users and equipment.

A user may enter commands and information into computing device **1102** through one or more input devices **1130** and may receive information from computing device **1102** through one or more output devices **1150**. Input device(s) **1130** may include one or more of touch screen **1132**, microphone **1134**, camera **1136**, physical keyboard **1138** and/or trackball **1140** and output device(s) **1150** may include one or more of speaker **1152** and display **1154**. Each of input device(s) **1130** and output device(s) **1150** may be integral to computing device **1102** (e.g., built into a housing of computing device **1102**) or external to computing device **1102** (e.g., communicatively coupled wired or wirelessly to computing device **1102** via wired interface(s) **1180** and/or wireless modem(s) **1160**). Further input devices **1130** (not shown) can include a Natural User Interface (NUI), a pointing device (computer mouse), a joystick, a video game controller, a scanner, a touch pad, a stylus pen, a voice recognition system to receive voice input, a gesture recognition system to receive gesture input, or the like. Other possible output devices (not shown) can include piezoelectric or other haptic output devices. Some devices can serve more than one input/output function. For instance, display **1154** may display information, as well as operating as touch screen **1132** by receiving user commands and/or other information (e.g., by touch, finger gestures, virtual keyboard, etc.) as a user interface. Any number of each type of input device(s) **1130** and output device(s) **1150** may be present, including multiple microphones **1134**, multiple cameras **1136**, multiple speakers **1152**, and/or multiple displays **1154**.

One or more wireless modems **1160** can be coupled to antenna(s) (not shown) of computing device **1102** and can support two-way communications between processor **1110** and devices external to computing device **1102** through network **1104**, as would be understood to persons skilled in the relevant art(s). Wireless modem **1160** is shown generically and can include a cellular modem **1166** for communicating with one or more cellular networks, such as a GSM network for data and voice communications within a single cellular network, between cellular networks, or between the mobile device and a public switched telephone network (PSTN). Wireless modem **1160** may also or alternatively include other radio-based modem types, such as a BLUETOOTH modem **1164** (also referred to as a "BLUETOOTH device") and/or WI-FI **1162** modem (also referred to as an "wireless adaptor"). WI-FI modem **1162** is configured to communicate with an access point or other remote WI-FI-capable device according to one or more of the wireless network protocols based on the IEEE (Institute of Electrical and Electronics Engineers) 802.11 family of standards, commonly used for local area networking of devices and Internet access. BLUETOOTH modem **1164** is configured to communicate with another BLUETOOTH-capable device according to the BLUETOOTH short-range wireless technology standard(s) such as IEEE 802.15.1 and/or managed by the BLUETOOTH Special Interest Group (SIG).

Computing device **1102** can further include power supply **1182**, LI receiver **1184**, accelerometer **1186**, and/or one or more wired interfaces **1180**. Example wired interfaces **1180** include a USB port, IEEE 1394 (FireWire) port, a RS-232 port, an HDMI (High-Definition Multimedia Interface) port (e.g., for connection to an external display), a DisplayPort port (e.g., for connection to an external display), an audio port, an Ethernet port, and/or an Apple® Lightning® port, the purposes and functions of each of which are well known to persons skilled in the relevant art(s). Wired interface(s) **1180** of computing device **1102** provide for wired connections between computing device **1102** and network **1104**, or between computing device **1102** and one or more devices/peripherals when such devices/peripherals are external to computing device **1102** (e.g., a pointing device, display **1154**, speaker **1152**, camera **1136**, physical keyboard **1138**, etc.). Power supply **1182** is configured to supply power to each of the components of computing device **1102** and may receive power from a battery internal to computing device **1102**, and/or from a power cord plugged into a power port of computing device **1102** (e.g., a USB port, an A/C power port). LI receiver **1184** may be used for location determination of computing device **1102** and may include a satellite navigation receiver such as a Global Positioning System (GPS) receiver or may include other type of location determiner configured to determine location of computing device **1102** based on received information (e.g., using cell tower triangulation, etc.). Accelerometer **1186** may be present to determine an orientation of computing device **1102**.

Note that the illustrated components of computing device **1102** are not required or all-inclusive, and fewer or greater numbers of components may be present as would be recognized by one skilled in the art. For example, computing device **1102** may also include one or more of a gyroscope, barometer, proximity sensor, ambient light sensor, digital compass, etc. Processor **1110** and memory **1156** may be co-located in a same semiconductor device package, such as being included together in an integrated circuit chip, FPGA, or system-on-chip (SOC), optionally along with further components of computing device **1102**.

In embodiments, computing device **1102** is configured to implement any of the above-described features of flowcharts herein. Computer program logic for performing any of the operations, steps, and/or functions described herein may be stored in storage **1120** and executed by processor **1110**.

In some embodiments, server infrastructure **1170** may be present in computing environment **1100** and may be communicatively coupled with computing device **1102** via network **1104**. Server infrastructure **1170**, when present, may be a network-accessible server set (e.g., a cloud-based environment or platform). As shown in FIG. **11**, server infrastructure **1170** includes clusters **1172**. Each of clusters **1172** may comprise a group of one or more compute nodes and/or a group of one or more storage nodes. For example, as shown in FIG. **11**, cluster **1172** includes nodes **1174**. Each of nodes **1174** are accessible via network **1104** (e.g., in a "cloud-based" embodiment) to build, deploy, and manage applications and services. Any of nodes **1174** may be a storage node that comprises a plurality of physical storage disks, SSDs, and/or other physical storage devices that are accessible via network **1104** and are configured to store data associated with the applications and services managed by nodes **1174**. For example, as shown in FIG. **11**, nodes **1174** may store application data **1178**.

Each of nodes **1174** may, as a compute node, comprise one or more server computers, server systems, and/or computing devices. For instance, a node **1174** may include one or more of the components of computing device **1102** disclosed herein. Each of nodes **1174** may be configured to execute one or more software applications (or "applications") and/or services and/or manage hardware resources (e.g., processors, memory, etc.), which may be utilized by users (e.g., customers) of the network-accessible server set. For example, as shown in FIG. **11**, nodes **1174** may operate application programs **1176**. In an implementation, a node of nodes **1174** may operate or comprise one or more virtual machines, with each virtual machine emulating a system architecture (e.g., an operating system), in an isolated manner, upon which applications such as application programs **1176** may be executed.

In an embodiment, one or more of clusters **1172** may be co-located (e.g., housed in one or more nearby buildings with associated components such as backup power supplies, redundant data communications, environmental controls, etc.) to form a datacenter, or may be arranged in other manners. Accordingly, in an embodiment, one or more of clusters **1172** may be a datacenter in a distributed collection of datacenters. In embodiments, exemplary computing environment **1100** comprises part of a cloud-based platform such as Amazon Web Services® of Amazon Web Services, Inc. or Google Cloud Platform™ of Google LLC, although these are only examples and are not intended to be limiting.

In an embodiment, computing device **1102** may access application programs **1176** for execution in any manner, such as by a client application and/or a browser at computing device **1102**. Example browsers include Microsoft Edge® by Microsoft Corp. of Redmond, Washington, Mozilla Firefox®, by Mozilla Corp. of Mountain View, California, Safari®, by Apple Inc. of Cupertino, California, and Google® Chrome by Google LLC of Mountain View, California.

For purposes of network (e.g., cloud) backup and data security, computing device **1102** may additionally and/or alternatively synchronize copies of application programs **1114** and/or application data **1116** to be stored at network-based server infrastructure **1170** as application programs **1176** and/or application data **1178**. For instance, operating system **1112** and/or application programs **1114** may include a file hosting service client, such as Microsoft® OneDrive® by Microsoft Corporation, Amazon Simple Storage Service (Amazon S3)® by Amazon Web Services, Inc., Dropbox® by Dropbox, Inc., Google Drive™ by Google LLC, etc., configured to synchronize applications and/or data stored in storage **1120** at network-based server infrastructure **1170**.

In some embodiments, on-premises servers **1192** may be present in computing environment **1100** and may be communicatively coupled with computing device **1102** via network **1104**. On-premises servers **1192**, when present, are hosted within an organization's infrastructure and, in many cases, physically onsite of a facility of that organization. On-premises servers **1192** are controlled, administered, and maintained by IT (Information Technology) personnel of the organization or an IT partner to the organization. Application data **1198** may be shared by on-premises servers **1192** between computing devices of the organization, including computing device **1102** (when part of an organization) through a local network of the organization, and/or through further networks accessible to the organization (including the Internet). Furthermore, on-premises servers **1192** may serve applications such as application programs **1196** to the computing devices of the organization, including computing device **1102**. Accordingly, on-premises servers **1192** may include storage **1194** (which includes one or more physical storage devices such as storage disks and/or SSDs) for storage of application programs **1196** and application data **1198** and may include one or more processors for execution of application programs **1196**. Still further, computing device **1102** may be configured to synchronize copies of application programs **1114** and/or application data **1116** for backup storage at on-premises servers **1192** as application programs **1196** and/or application data **1198**.

Embodiments described herein may be implemented in one or more of computing device **1102**, network-based server infrastructure **1170**, and on-premises servers **1192**. For example, in some embodiments, computing device **1102** may be used to implement systems, clients, or devices, or components/subcomponents thereof, disclosed elsewhere herein. In other embodiments, a combination of computing device **1102**, network-based server infrastructure **1170**, and/or on-premises servers **1192** may be used to implement the systems, clients, or devices, or components/subcomponents thereof, disclosed elsewhere herein.

As used herein, the terms "computer program medium," "computer-readable medium," and "computer-readable storage medium," etc., are used to refer to physical hardware media. Examples of such physical hardware media include any hard disk, optical disk. SSD, other physical hardware media such as RAMs, ROMs, flash memory, digital video disks, zip disks, MEMs (microelectronic machine) memory, nanotechnology-based storage devices, and further types of physical/tangible hardware storage media of storage **1120**. Such computer-readable media and/or storage media are distinguished from and non-overlapping with communication media and propagating signals (do not include communication media and propagating signals). Communication media embodies computer-readable instructions, data structures, program modules or other data in a modulated data signal such as a carrier wave. The term "modulated data signal" means a signal that has one or more of its characteristics set or changed in such a manner as to encode information in the signal. By way of example, and not limitation, communication media includes wireless media such as acoustic, RF, infrared and other wireless media, as well as wired media. Embodiments are also directed to such communication media that are separate and non-overlapping with embodiments directed to computer-readable storage media.

As noted above, computer programs and modules (including application programs **1114**) may be stored in storage **1120**. Such computer programs may also be received via wired interface(s) **1180** and/or wireless modem(s) **1160** over network **1104**. Such computer programs, when executed or loaded by an application, enable computing device **1102** to implement features of embodiments discussed herein.

Accordingly, such computer programs represent controllers of the computing device **1102**.

Embodiments are also directed to computer program products comprising computer code or instructions stored on any computer-readable medium or computer-readable storage medium. Such computer program products include the physical storage of storage **1120** as well as further physical storage types.

VI. Additional Example Embodiments

In an embodiment, a method, performed by a proxy server, including: receiving a first web page from a server; injecting program instructions into the first web page, the program instructions being configured to cause a client browser to: monitor user actions with respect to content of the first web page on behalf of the proxy server, detect the creation of an element of the first web page having a source that is a remote URL, and mark the URL with a marking based on the detection; transmitting the first web page to the client browser; receiving from the client browser a request that includes the URL and the marking; extracting the marking from the request and transmitting the request to the server; receiving, from the server, a response that includes a resource identified by the URL; determining that the response corresponds to the request; determining that the resource is in a first format that is rendered by the client browser using a file viewer that prevents the client browser from monitoring user actions with respect to the resource on behalf of the proxy server; responsive to the determining that the response corresponds to the request and the determining that the resource is in the first format: converting the resource from the first format to a second format that is rendered by the client browser in a manner that permits the client browser to monitor user actions with respect to the resource on behalf of the proxy server; and transmitting, to the client browser, the resource in the second format.

In an embodiment, the method further includes: receiving monitoring information from the client browser regarding a user action with respect to the resource; and blocking an event associated with the user action based at least on the monitoring information.

In an embodiment, the event comprises one of: copying a content of the resource; editing the resource; saving the resource; printing the resource; or downloading the resource.

In an embodiment, the element of the first web page comprises one of: an iframe HTML element; an object HTML element; or an embed HMTL element.

In an embodiment, the marking the URL comprises one of modifying the URL or appending the marking to the URL.

In an embodiment, the first format is a Portable Document Format (PDF), and the resource is a PDF file.

In an embodiment, the converting the resource from the first format to the second format comprises: converting the resource from the first format into a byte array; and generating a second web page that includes a script that when executed by the client browser causes the client browser to render the contents of the resource using the byte array; and wherein transmitting, to the client browser, the resource in the second format comprises: transmitting the second web page to the client browser.

In another embodiment, a system comprises: a processor; and a memory having computer-executable instructions stored thereon that, when executed by a processor, causes the processor to: receive a first web page from a server; inject program instructions into the first web page, the program instructions being configured to cause a client browser to: monitor user actions with respect to content of the first web page on behalf of the proxy server, detect the creation of an element of the first web page having a source that is a remote URL, and mark the URL with a marking based on the detection; transmit the first web page to the client browser; receive from the client browser a request that includes the URL and the marking; extract the marking from the request and transmit the request to the server; receive, from the server, a response that includes a resource identified by the URL; determine that the response corresponds to the request; determine that the resource is in a first format that is rendered by the client browser using a file viewer that prevents the client browser from monitoring user actions with respect to the resource on behalf of the proxy server; responsive to the determining that the response corresponds to the request and the determining that the resource is in the first format: convert the resource from the first format to a second format that is rendered by the client browser in a manner that permits the client browser to monitor user actions with respect to the resource on behalf of the proxy server; and transmit, to the client browser, the resource in the second format.

In an embodiment, the instructions, when executed by the processor, further causes the system to: receive monitoring information from the client browser regarding a user action with respect to the resource; and block an event associated with the user action based at least on the monitoring information.

In an embodiment, the event comprises one of: copying a content of the resource; editing the resource; saving the resource; printing the resource; or downloading the resource.

In an embodiment, the element of the first web page comprises one of: an iframe HTML element; an object HTML element; or an embed HMTL element.

In an embodiment, the marking the URL comprises one of modifying the URL or appending the marking to the URL.

In an embodiment, the first format is a Portable Document Format (PDF), and the resource is a PDF file.

In an embodiment, the converting the resource from the first format to the second format comprises: converting the resource from the first format into a byte array; and generating a second web page that includes a script that when executed by the client browser causes the client browser to render the contents of the resource using the byte array; and wherein transmitting, to the client browser, the resource in the second format comprises: transmitting the second web page to the client browser.

In another embodiment, a computer-readable storage medium has computer-executable instructions stored thereon that, when executed by a processor, causes a processor to: receive a first web page from a server; inject program instructions into the first web page, the program instructions being configured to cause a client browser to: monitor user actions with respect to content of the first web page on behalf of the proxy server, detect the creation of an element of the first web page having a source that is a remote URL, and mark the URL with a marking based on the detection; transmit the first web page to the client browser; receive from the client browser a request that includes the URL and the marking; extract the marking from the request and transmit the request to the server; receive, from the server, a response that includes a resource identified by the URL; determine that the response corresponds to the request; determine that the resource is in a first format that is rendered by the client browser using a file viewer that prevents the client browser from monitoring user actions with respect to the resource on behalf of the proxy server; responsive to the determining that the response corresponds to the request and the determining that the resource is in the first format: convert the resource from the first format to a second format that is rendered by the client browser in a manner that permits the client browser to monitor user actions with respect to the resource on behalf of the proxy server; and transmit, to the client browser, the resource in the second format.

In an embodiment, the instructions, when executed by the processor, further causes the system to: receive monitoring information from the client browser regarding a user action with respect to the resource; and block an event associated with the user action based at least on the monitoring information.

In an embodiment, the event comprises one of: copying a content of the resource; editing the resource; saving the resource; printing the resource; or downloading the resource.

In an embodiment, the element of the first web page comprises one of: an iframe HTML element; an object HTML element; or an embed HMTL element.

In an embodiment, the marking the URL comprises one of modifying the URL or appending the marking to the URL.

In an embodiment, the first format is a Portable Document Format (PDF), and the resource is a PDF file.

In an embodiment, the converting the resource from the first format to the second format comprises: converting the resource from the first format into a byte array; and generating a second web page that includes a script that when executed by the client browser causes the client browser to render the contents of the resource using the byte array; and wherein transmitting, to the client browser, the resource in the second format comprises: transmitting the second web page to the client browser.

VII. Conclusion

References in the specification to "one embodiment," "an embodiment," "an example embodiment," etc., indicate that the embodiment described may include a particular feature, structure, or characteristic, but every embodiment may not necessarily include the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to effect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.

In the discussion, unless otherwise stated, adjectives such as "substantially" and "about" modifying a condition or relationship characteristic of a feature or features of an embodiment of the disclosure, are understood to mean that the condition or characteristic is defined to within tolerances that are acceptable for operation of the embodiment for an application for which it is intended. Furthermore, where "based on" is used to indicate an effect being a result of an indicated cause, it is to be understood that the effect is not required to only result from the indicated cause, but that any number of possible additional causes may also contribute to the effect. Thus, as used herein, the term "based on" should be understood to be equivalent to the term "based at least on."

While various embodiments of the present disclosure have been described above, it should be understood that they have been presented by way of example only, and not limitation. It will be understood by those skilled in the relevant art(s) that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined in the appended claims. Accordingly, the breadth and scope of the present invention should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.

What is claimed:

1. A method, performed by a proxy server, comprising:

receiving a first web page from a web server;

injecting a client-side script into the first web page to form a modified first web page, the client-side script being configured to cause a client browser to:

detect client-side creation of a markup language element in the modified first web page having a source uniform resource locator (URL) that references a remote resource, and

mark, responsive to detecting client-side creation of the markup language element, the URL by modifying the URL to include a marking;

transmitting the modified first web page to the client browser;

receiving from the client browser a first request that includes the URL and the marking;

extracting the marking from the first request to form a second request and transmitting the second request to the web server;

receiving, from the web server, a response that includes a resource identified by the URL;

determining that the response corresponds to the second request;

determining that the resource is in a first format that limits the ability of the proxy server to monitor user actions with respect to the resource through the client browser;

responsive to the determining that the response corresponds to the second request and the determining that the resource is in the first format:

converting the resource from the first format to a second format that enables the proxy server to monitor user actions with respect to the resource through the client browser; and

transmitting, to the client browser, the resource in the second format.

2. The method of claim **1**, further comprising:

receiving monitoring information from the client browser regarding a user action with respect to the resource; and

blocking an event associated with the user action based at least on the monitoring information.

3. The method of claim **2**, wherein the event comprises one of:

copying a content of the resource;

editing the resource;

saving the resource;

printing the resource; or

downloading the resource.

4. The method of claim **1**, wherein the markup language element of the first web page comprises one of:

an iframe HTML element;

an object HTML element; or

an embed HMTL element.

5. The method of claim **1**, wherein marking the URL comprises appending the marking to the URL.

6. The method of claim **1**, wherein the first format is a Portable Document Format (PDF), and the resource is a PDF file.

7. The method of claim **1**, wherein converting the resource from the first format to the second format comprises:
converting the resource from the first format into a byte array; and
generating a second web page that includes a script that, when executed by the client browser, causes the client browser to render the contents of the resource using the byte array; and
wherein transmitting, to the client browser, the resource in the second format comprises:
transmitting the second web page to the client browser.

8. A system comprising:
a processor; and
a memory having computer-executable instructions stored thereon that, when executed by a processor, causes the processor to:
receive a first web page from a web server;
inject a client-side script into the first web page to form a modified first web page, the client-side script being configured to cause a client browser to:
detect client-side creation of a markup language element in the modified first web page having a source uniform resource locator (URL) that references a remote resource, and
mark, responsive to detecting client-side creation of the markup language element, the URL to include a marking;
transmit the modified first web page to the client browser;
receive from the client browser a first request that includes the URL and the marking;
extract the marking from the first request to form a second request and transmit the second request to the web server;
receive, from the web server, a response that includes a resource identified by the URL;
determine that the response corresponds to the second request;
determine that the resource is in a first format that limits the ability of the proxy server to monitor user actions with respect to the resource through the client browser;
responsive to the determining that the response corresponds to the second request and the determining that the resource is in the first format:
convert the resource from the first format to a second format that enables the proxy server to monitor user actions with respect to the resource through the client browser; and
transmit, to the client browser, the resource in the second format.

9. The system of claim **8**, wherein the instructions, when executed by the processor, further causes the system to:
receive monitoring information from the client browser regarding a user action with respect to the resource; and
block an event associated with the user action based at least on the monitoring information.

10. The system of claim **9**, wherein the event comprises one of:
copying a content of the resource;
editing the resource;
saving the resource;
printing the resource; or
downloading the resource in the first format.

11. The system of claim **8**, wherein the markup language element of the first web page comprises one of:

an iframe HTML element;
an object HTML element; or
an embed HMTL element.

12. The system of claim **8**, wherein marking the URL comprises appending the marking to the URL.

13. The system of claim **8**, wherein the first format is a Portable Document Format (PDF), and the resource is a PDF file.

14. The system of claim **8**, wherein converting the resource from the first format to the second format comprises:
converting the resource from the first format into a byte array; and
generating a second web page that includes a script that when executed by the client browser causes the client browser to render the contents of the resource using the byte array; and
wherein transmitting, to the client browser, the resource in the second format comprises:
transmitting the second web page to the client browser.

15. A computer-readable storage medium having computer-executable instructions stored thereon that, when executed by a processor, causes the processor to:
receive a first web page from a web server;
inject a client-side script into the first web page to form a modified first web page, the client-side script being configured to cause a client browser to:
detect client-side creation of a markup language element in the modified first web page having a source uniform resource locator (URL) that references a remote resource, and
mark, responsive to detecting client-side creation of the markup language element, the URL by modifying the URL to include a marking;
transmit the modified first web page to the client browser;
receive from the client browser a first request that includes the URL and the marking;
extract the marking from the first request to form a second request and transmit the second request to the web server;
receive, from the web server, a response that includes a resource identified by the URL;
determine that the response corresponds to the second request;
determine that the resource is in a first format that is associated limits the ability of the proxy server to monitor user actions with respect to the resource through the client browser;
responsive to the determining that the response corresponds to the second request and the determining that the resource is in the first format:
convert the resource from the first format to a second format that enables the proxy server to monitor user actions with respect to the resource through the client browser; and
transmit, to the client browser, the resource in the second format.

16. The computer-readable medium of claim **15**, wherein the instructions, when executed by the processor, further causes the processor to:
receive monitoring information from the client browser regarding a user action with respect to the resource; and
block an event associated with the user action based at least on the monitoring information.

17. The computer-readable medium of claim **16**, wherein the event comprises one of:

copying a content of the resource;
editing the resource;
saving the resource;
printing the resource; or
downloading the resource in the first format.

18. The computer-readable medium of claim **15**, wherein the markup language element of the first web page comprises one of:
an iframe HTML element;
an object HTML element; or
an embed HMTL element.

19. The computer-readable medium of claim **15**, wherein the first format is a Portable Document Format (PDF), and the resource is a PDF file.

20. The computer-readable medium of claim **15**, wherein converting the resource comprises:
wherein converting the resource from the first format to the second format comprises:
converting the resource from the first format into a byte array; and
generating a second web page that includes a script that when executed by the client browser causes the client browser to render the contents of the resource using the byte array; and
wherein transmitting, to the client browser, the resource in the second format comprises:
transmitting the second web page to the client browser.

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