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(54) **SYSTEM AND METHOD FOR NETWORK CACHING**

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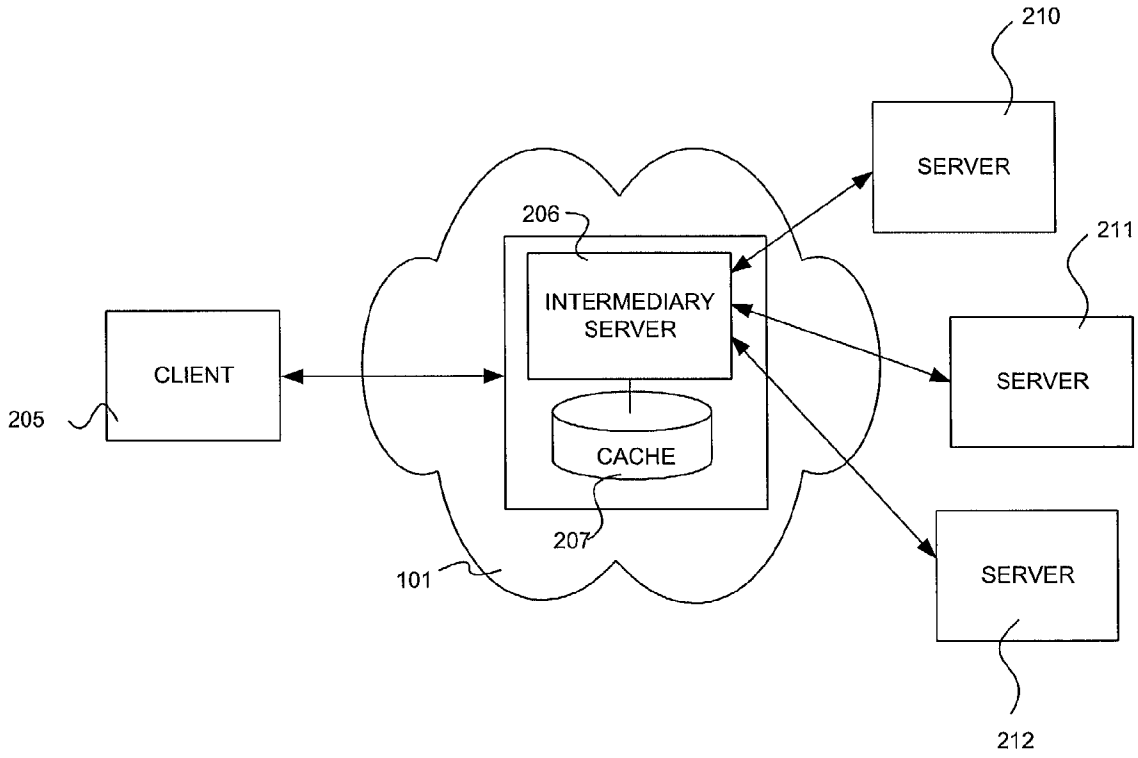
(57) **ABSTRACT**

A system and method for caching network resources in an intermediary server topologically located between a client and a server in a network. The intermediate server preferably caches at both a back-end location and a front-end location. Intermediary server includes a cache and methods for loading content into the cache as according to rules specified by a site owner. Optionally, content can be proactively loaded into the cache to include content not yet requested. In another option, requests can be held at the cache when a prior request for similar content is pending.



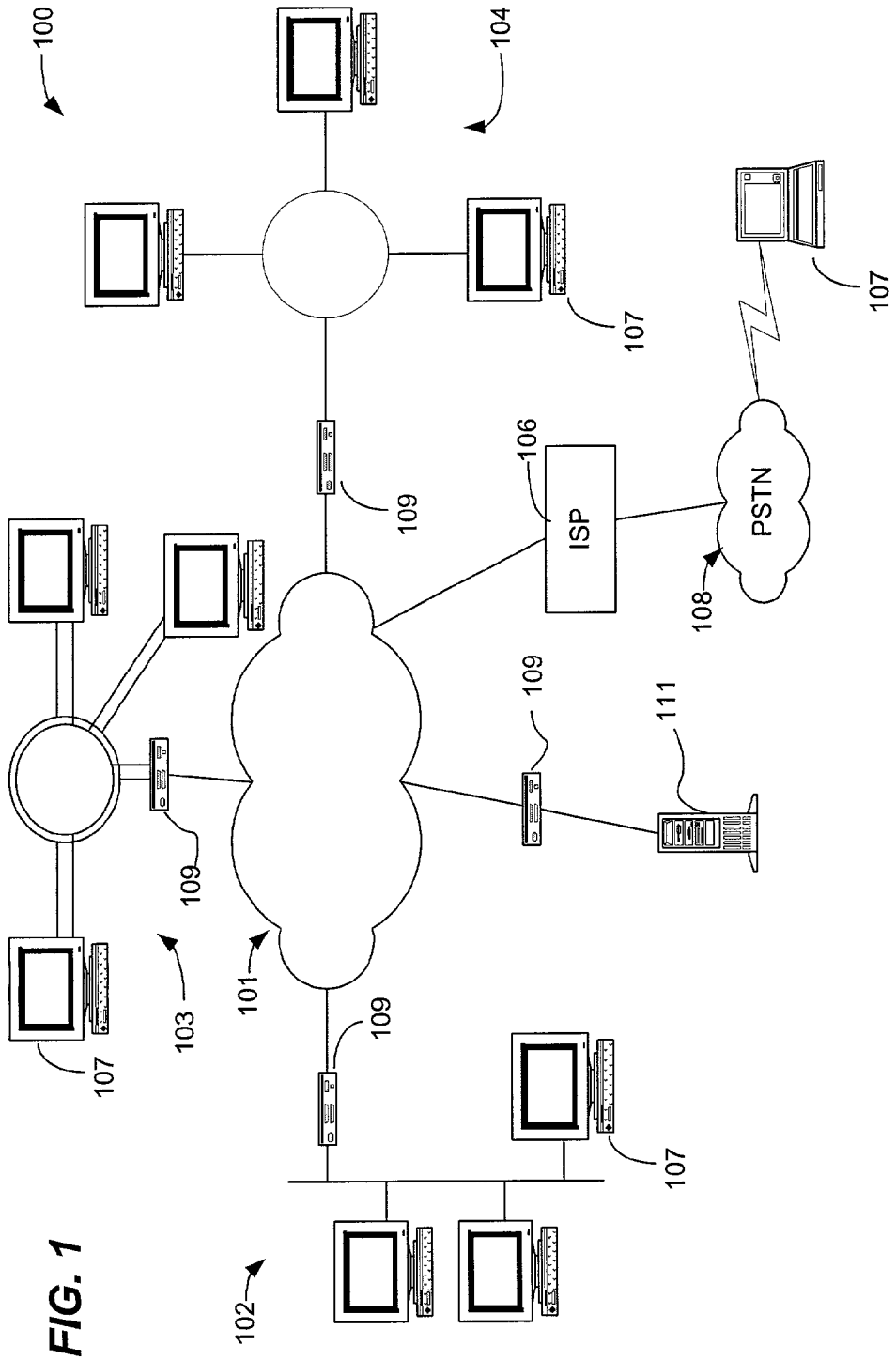

100
104
107
107
109
106
ISP
PSTN
108
109
111
109
109
103
101
107
107
102

FIG. 1

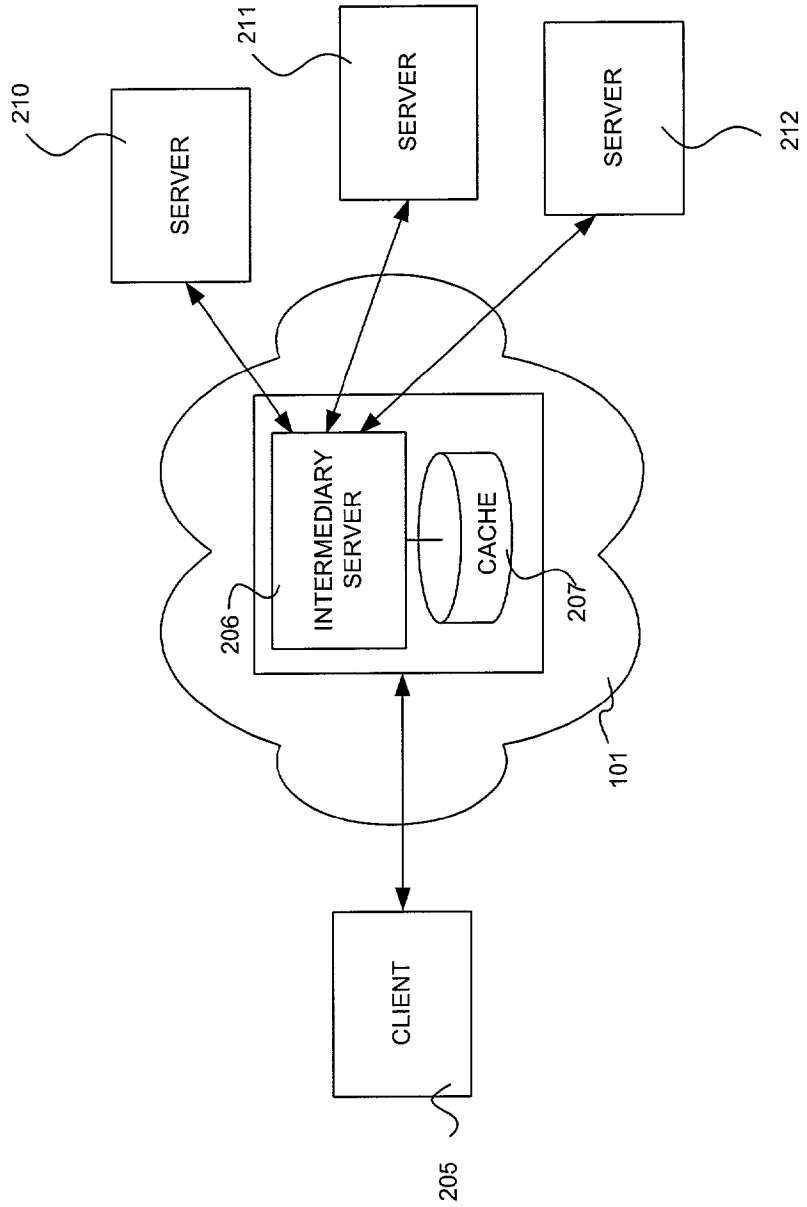

210
SERVER
211
SERVER
SERVER
212
INTERMEDIARY SERVER
206
CACHE
207
101
CLIENT
205

FIG. 2A

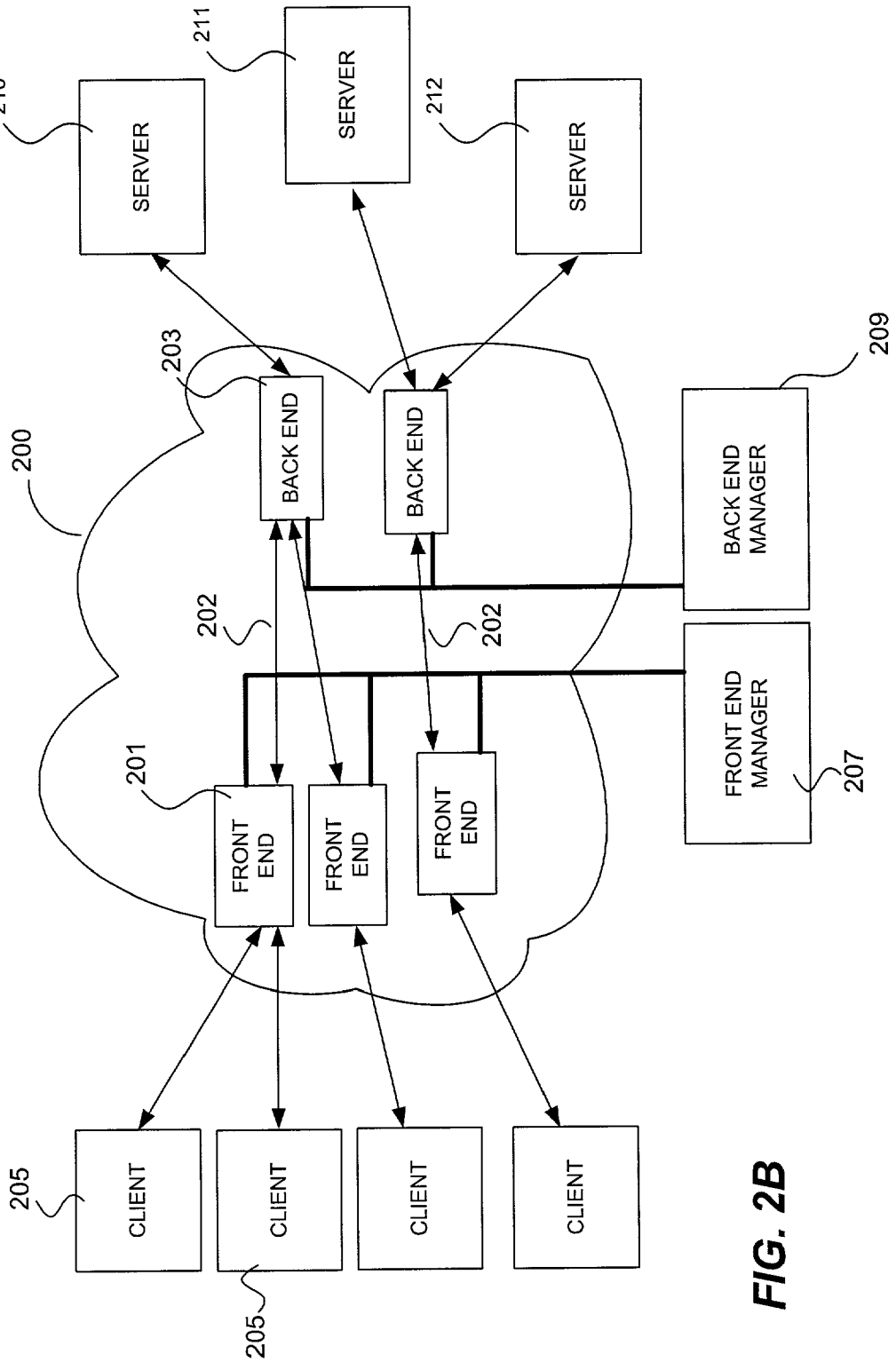

210
SERVER
211
SERVER
212
SERVER
200
203
BACK END
BACK END
209
BACK END MANAGER
202
202
201
FRONT END
FRONT END
FRONT END
FRONT END MANAGER
207
205
CLIENT
CLIENT
CLIENT
CLIENT
205

FIG. 2B

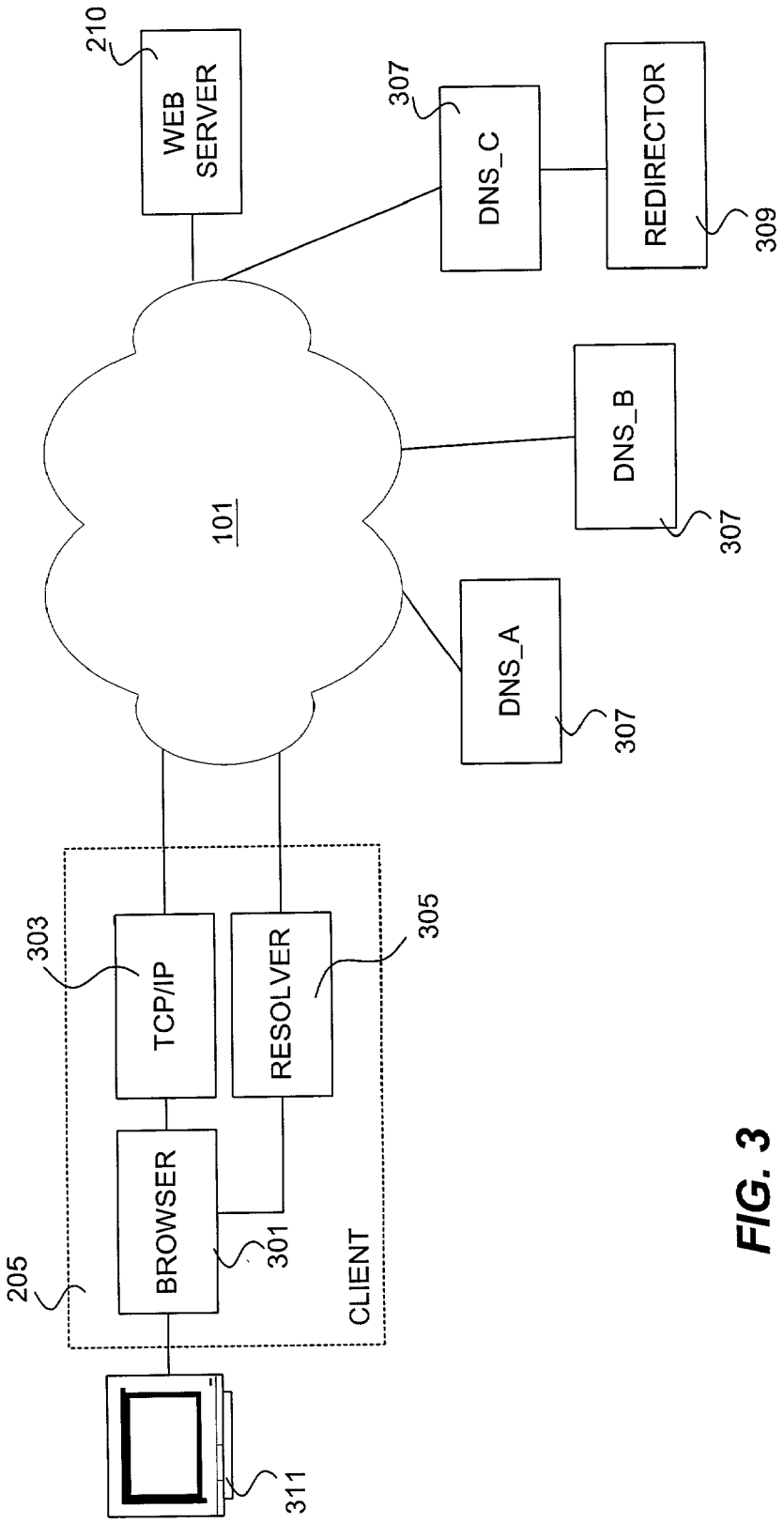

210
WEB SERVER
307
DNS_C
REDIRECTOR
309
101
DNS_B
307
DNS_A
307
303
TCP/IP
RESOLVER
305
BROWSER
301
CLIENT
205
311

FIG. 3

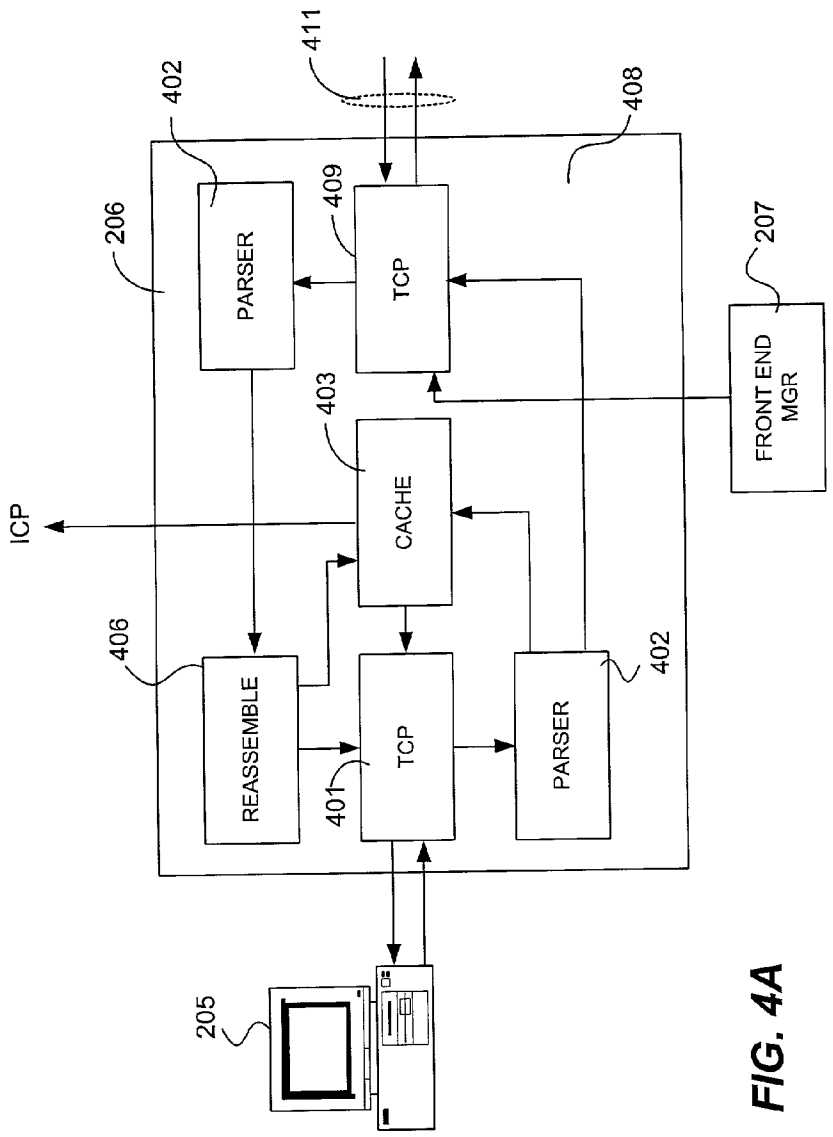

411
402
408
206
PARSER
409
TCP
207
FRONT END MGR
403
CACHE
ICP
406
REASSEMBLE
TCP
401
PARSER
402
205

FIG. 4A

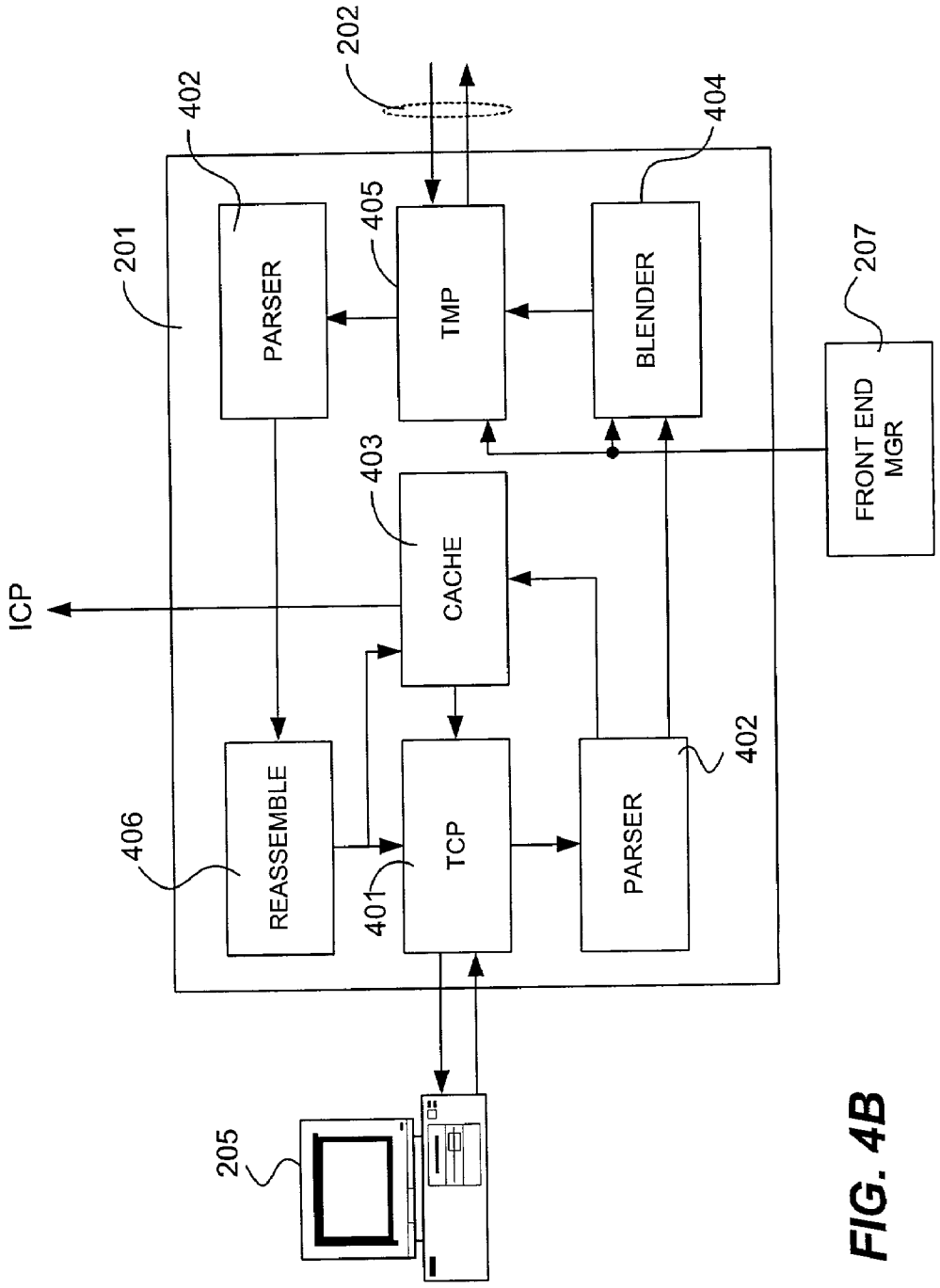

202
402
404
405
201
PARSER
TMP
BLENDER
207
FRONT END MGR
403
CACHE
ICP
402
406
REASSEMBLE
TCP
PARSER
401
205

FIG. 4B

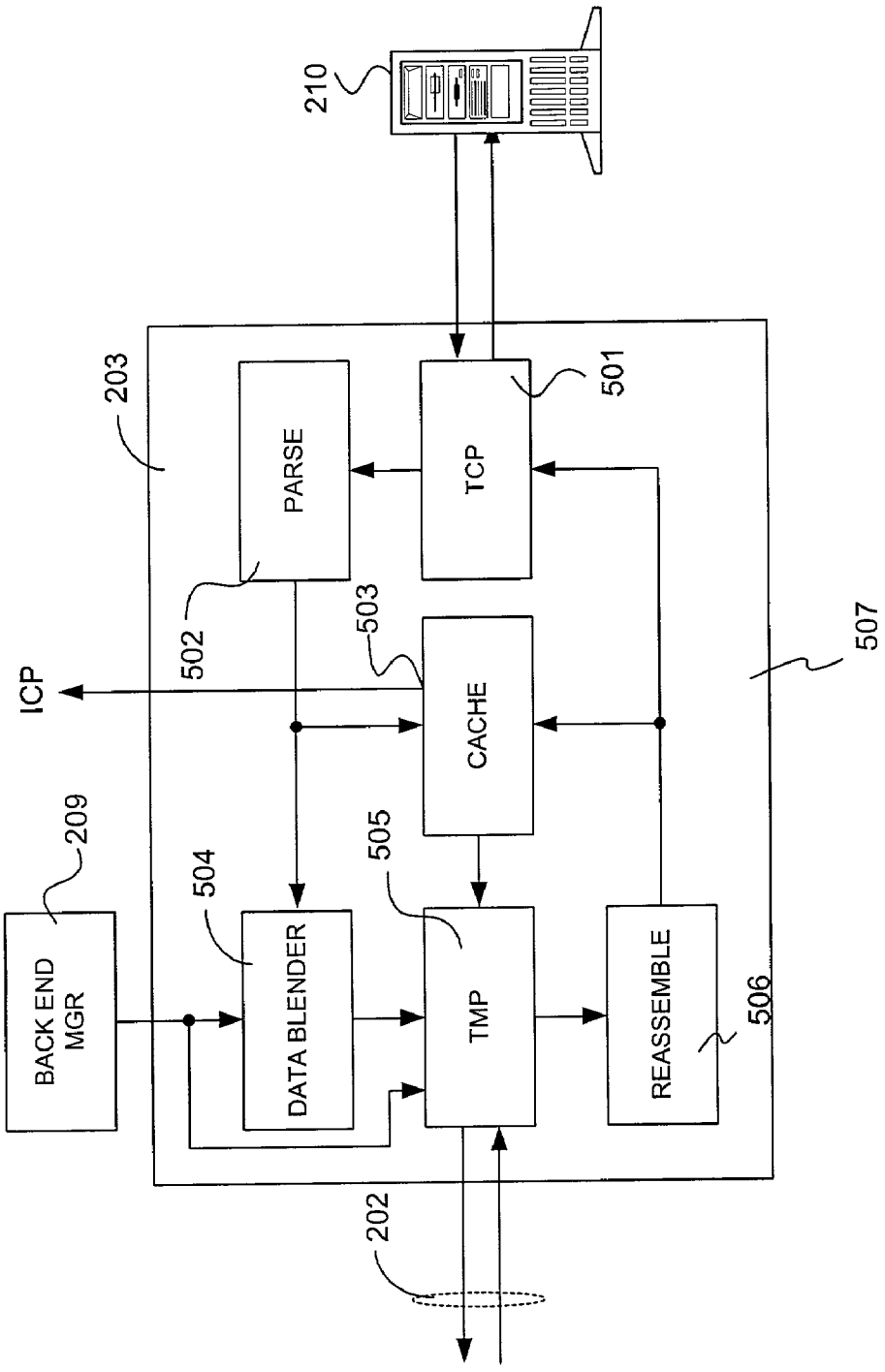

210
203
PARSE
TCP
501
502
503
507
ICP
CACHE
209
504
505
BACK END MGR
DATA BLENDER
TMP
REASSEMBLE
506
202

FIG. 5

SYSTEM AND METHOD FOR NETWORK CACHING

RELATED APPLICATIONS

[0001] The present invention claims priority from U.S. Provisional Patent Application No. 60/197,490 entitled CONDUCTOR GATEWAY filed on Apr. 17, 2000.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention.

[0003] The present invention relates, in general, to network information access and, more particularly, to software, systems and methods for caching request and/or response traffic in a data communication system.

[0004] 2. Relevant Background

[0005] Increasingly, business data processing systems, entertainment systems, and personal communications systems are implemented by computers across networks that are interconnected by internetworks (e.g., the Internet). The Internet is rapidly emerging as the preferred system for distributing and exchanging data. Data exchanges support applications including electronic commerce, broadcast and multicast messaging, videoconferencing, gaming, and the like.

[0006] Currently, Internet services are implemented as client-server systems. The client is typically implemented as a web browser application executing on a network-connected workstation or personal computer, although mail, news, file transfer and other Internet services are relatively common. The server is typically implemented as a web server at a fixed network address. A client enters a uniform resource locator (URL) or selects a link pointing to a URL where the URL identifies the server and particular content from the server that is desired. The client request traverses the network to be received by the server.

[0007] The server then obtains data necessary to compose a response to the client request. For example, the response may comprise a hypertext markup language (HTML) document in a web-based application. HTML and other markup language documents comprise text, graphics, active components, as well as references to files and resources at other servers. In the case of static web pages, the web server may simply retrieve the page from a file system, and send it in an HTTP response packet using conventional TCP/IP protocols and interfaces. In the case of dynamically generated pages, the web server obtains data necessary to generate a responsive page, typically through one or more database accesses. The web server then generates a page, typically a markup language document, that incorporates the retrieved data. Once generated, the web server sends the dynamic page in a manner similar to a static page.

[0008] Many web sites have pages or page elements that are viewed by many users, and appear the same to all viewers. These page elements include data in the form of text files, markup language documents, graphics files and the like, as well as active content such as scripts, applets, active controls and the like. It is an inefficient use of bandwidth and server resources to resend the exact same data time after time from the server to different users.

[0009] Caching is designed to store copies of pages or page elements in caches located closer to the clients that are requesting the pages. When a web page can be served out of a cache, the page is returned more quickly to the user. Caching reduces Internet traffic, for example, by storing pages at the Internet service provider (ISP) the first time a user accesses the pages so that subsequent requests for the same page do not require that the origin server be contacted. Another advantage of caching is that because fewer requests reach the origin server, the origin server load is reduced for a given number of users.

[0010] A key issue in systems that cache Internet resources is control over the caching behavior. Conventional Internet caching methods allow a site owner to indicate desired caching behavior by specifying cache control parameters in the HTTP packet headers. While HTTP v1.1 specifications, defined in IETF RFC 2068, allow cache parameters, many other network protocols do not offer these features. Also, while a web site owner does not have actual control over the many caching mechanisms in the Internet and so cannot be positive that the desired caching behavior will in fact be implemented at each and every cache. As a result, many site owners simply specify all web pages as non-cacheable to minimize risks associated with delivery of stale content, thereby forgoing the benefits of caching. A need exists for a system and method that provides for caching under control of rules specified by site owners.

[0011] Another limitation of existing Internet caching mechanisms is they lack effective means that enable a site owner to control the contents of caches. Most cache systems are passive response caches that will cache a copy of a response to a given request, but will not place content in a cache before a specific request. In some applications, however, performance can be improved if the web site could controllably load the cache by effectively pushing content from the web server out to the cache. For example, when a server is under heavy load, it may be desirable to expand the cache contents to explicitly prevent user requests from hitting the central server. Hence, a need exists for systems and methods enabling web site owners to actively manage network caches.

[0012] When the content being cached includes large files, it may take a significant amount of time to communicate the response and fill the cache. Examples include multimedia files, multicast or broadcast files, software updates, and the like. In these cases, the likelihood that a subsequent request for the same content will come in while the initial request is being filled is greater. Existing cache solutions will continue to forward requests to the server until the entire set of static files is cached so that the benefit of the cache is non-optimal. Particularly in situations where large files (e.g., streaming video, media, software updates, and the like) it is contemplated that substantially simultaneous requests for the same content will be frequent. Accordingly, a need exists for a cache system and method that performs request merging to postpone requests while a prior request for the same content is pending or "in-flight".

[0013] Existing cache solutions are asynchronous in that the cache mechanism is unaware of operational and timing details within the origin server that might affect cache performance. For example, a particular web page might be updated within the origin server every minute or every

half-hour. In such cases, the freshest content is obtained just after the origin server update, however, because the cache does not know the update cycle, it cannot adjust the caching behavior to maximize the delivery of fresh content.

SUMMARY OF THE INVENTION

[0014] Briefly stated, the present invention involves a system for caching network resources in an intermediary server topologically located between a client and a server in a network. The intermediate server preferably caches at both a back-end location and a front-end location. Intermediary server includes a cache and methods for loading content into the cache as according to rules specified by a site owner. Optionally, content can be proactively loaded into the cache to include content not yet requested. In another option, requests can be held at the cache when a prior request for similar content is pending.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] **FIG. 1** illustrates a general distributed computing environment in which the present invention is implemented;

[0016] **FIG. 2A** shows in block-diagram form significant components of a system in accordance with the present invention;

[0017] **FIG. 2B** shows in block-diagram form significant components of an alternative system in accordance with the present invention;

[0018] **FIG. 3** shows a domain name system used in an implementation of the present invention;

[0019] **FIG. 4A** shows components of **FIG. 2A** in greater detail;

[0020] **FIG. 4B** illustrates components of **FIG. 2B** in greater detail; and

[0021] **FIG. 5** shows back-end components of **FIG. 2B** in greater detail.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0022] The present invention involves systems and methods for providing improved performance in network communications through the use of a caching web server located at the client-side "edge" of a network environment. This means that the web server implementing the cache in accordance with the present invention is logically proximate to the client application generating requests for web pages. It is contemplated that at least some of the requested content can be supplied by content data and resources persistently stored in a data store accessible by the web server, but that at least some content will be obtained from remote network resources such as remote data stores, remote web servers, and the like. This remote data is obtained by the web server on behalf of a requesting client and then cached so that it can be used to respond to subsequent requests. In a sense, the web server acts as a hybrid between a web server and a caching proxy server in that it can supply both original content as well as cached remote content.

[0023] The present invention is illustrated and described in terms of a distributed computing environment such as an enterprise computing system using public communication channels such as the Internet. However, an important feature of the present invention is that it is readily scaled upwardly and downwardly to meet the needs of a particular application. Accordingly, unless specified to the contrary, the present invention is applicable to significantly larger, more complex network environments, including wireless network environments, as well as small network environments such as conventional LAN systems.

[0024] Essentially, an intermediary server(s) is placed in communication with the client and server to participate in the request/response traffic between the client and server. In this position, the intermediary can be given specific knowledge of the configuration, capabilities and preferred formats of both the clients and servers. The intermediary implements a cache for storing content including web-pages, web page components, files, graphics, program code and the like that are subject to client requests. Moreover, an intermediary server can modify the data that is subject to a client request and cache the modified data. For example, multimedia files may be formatted to a particular standard, such as an MPEG standard, and cached in the modified form such that subsequent requests can be filled from cache without required formatting processes.

[0025] Although the present invention may use conventional cache instructions provided in HTTP headers, preferably the content includes caching parameters that provides independent instruction to the caching system of the present invention. In this manner, the caches of the present invention may provide caching services even where the content is marked uncacheable in the HTTP header.

[0026] Preferably, the cache contents are determinable by the site owner by allowing the site owner to cause the cache to be loaded with desired content. In this manner, content can be loaded into a cache before it is requested by a user based on a likelihood that it will be requested by a user. In this manner, a web site owner can explicitly prevent hits to the central server(s) by proactively sending content to a cache. For example, in the case of a small web site of a few megabytes of storage, the first hit to an index page may justify sending the entire site to the intermediary server that received the hit thereby preventing any further hits to the origin server.

[0027] Moreover, the home page or "index.html" page of the web site (i.e., the page most likely to be the first contact with a user) may be cached on the intermediary permanently or until the website provides an updated index page. A hit to the index page may result in serving the index page from the cache, and a request from the intermediary server to load the remainder of the site, the linked pages, or an intermediate set of pages into the cache while the user views the index.html page.

[0028] In general, the present invention involves a combination of passive caching (i.e., cache contents are selected based on prior requests) and active caching (i.e., cache contents are selected speculatively based on what is expected to be requested in the future). Speculative caching is used in a variety of environments, such as disk caching, where data has a predictable spatial relationship with other data. However, in a network environment, particularly in a hyper-linked environment, the spatial relationships cannot be relied upon. HTML, for example, is specifically designed to access data in a non-sequential, user-controlled manner.

[0029] Accordingly, the present invention provides a system and method in which a current request, or a response to that request, can be used as a basis for both passively and actively caching network resources associated with that request/response. A response can be passively cached in a conventional manner. Additionally, however, the request and/or response can be analyzed to determine other material that can be actively cached, such as data linked to the response.

[0030] This additional data may include dynamically generated data. For example, a current request may include state information such as a cookie, that is intended to allow the origin server to personalize responses. The cache may be filled by making speculative requests to the server using the cookie so that the cache is filled with dynamically generated content. Alternatively, state information can be communicated from the server in the initial response in the form of parameters encoded in links within the response. The cache may be filled by making speculative requests using the links within the current response so that the cache is filled with dynamically generated content.

[0031] In this manner, a cache can be intelligently and efficiently populated with data that has a high likelihood of being requested in the future even though that data may be stored in a variety of files and servers. Hence, the present invention provides a means to explicitly prevent accesses to the origin server by moving content into the cache speculatively, before it is requested.

[0032] Alternatively, speculative caching may be based on server resources. A server under load may become less able to provide certain types of resources. For example, an e-commerce web server under a high shopping load may dedicate a large quantity of resources (i.e., I/O buffers and memory) to shopping cart processes. This may make resources for other activities (e.g., serving informational pages) scarce. In accordance with the present invention, an intermediary server is aware of server load and speculatively caches data that might otherwise tax scarce resources in the server itself.

[0033] While the examples herein largely involve web-based applications using markup language documents, web browsers and web servers, the teachings are readily extended to other types of client-server information exchange. For example, a database system can respond to an initial query by loading the entire database or a selected portion of a database into the cache of an intermediary server. Subsequent requests can be satisfied by the intermediary server. Likewise, a network file system (NFS) or file transfer protocol (FTP) system may respond to an initial hit for a top level directory by loading the cache of an intermediary server with files from all the branches of the directory or with a list of details for the files in the immediate subdirectories. These implementations are readily derived equivalents of the examples given herein.

[0034] In a particular implementation, the intermediary server is implemented by a front-end computer and a back-end computer that are coupled over a network. This enables either or both of the front-end and back-end computers to perform the caching functions as needed. In this configuration, a back-end cache will cache responses to multiple front-ends. Conversely, the front-end caches will cache responses received from multiple back-ends. Hence, each front-end and back-end cache is uniquely situated within the network topology to improve cache performance. For example, a back-end cache can readily identify cache contents with high hit rates and propagate that content to all or selected front-end caches. This will result in requests being filled in the front-end caches before they reach the back-ends.

[0035] **FIG. 1** shows an exemplary computing environment **100** in which the present invention may be implemented. Environment **100** includes a plurality of local networks such as Ethernet network **102**, FDDI network **103** and Token Ring network **104**. Essentially, a number of computing devices and groups of devices are interconnected through a network **101**. For example, local networks **102**, **103** and **104** are each coupled to network **101** through routers **109**. LANs **102**, **103** and **104** may be implemented using any available topology and may implement one or more server technologies including, for example UNIX, Novell, or Windows NT networks, or peer-to-peer type network. Each network will include distributed storage implemented in each device and typically includes some mass storage device coupled to or managed by a server computer. Network **101** comprises, for example, a public network such as the Internet or another network mechanism such as a fibre channel fabric or conventional WAN technologies.

[0036] Local networks **102**, **103** and **104** include one or more network appliances **107**. One or more network appliances **107** may be configured as an application and/or file server. Each local network **102**, **103** and **104** may include a number of shared devices (not shown) such as printers, file servers, mass storage and the like. Similarly, devices **111** may be shared through network **101** to provide application and file services, directory services, printing, storage, and the like. Routers **109** provide a physical connection between the various devices through network **101**. Routers **109** may implement desired access and security protocols to manage access through network **101**.

[0037] Network appliances **107** may also couple to network **101** through public switched telephone network **108** using copper or wireless connection technology. In a typical environment, an Internet service provider **106** supports a connection to network **101** as well as PSTN **108** connections to network appliances **107**.

[0038] Network appliances **107** may be implemented as any kind of network appliance having sufficient computational function to execute software needed to establish and use a connection to network **101**. Network appliances **107** may comprise workstation and personal computer hardware executing commercial operating systems such as Unix variants, Microsoft Windows, Macintosh OS, and the like. At the same time, some appliances **107** comprise portable or handheld devices using wireless connections through a wireless access provider such as personal digital assistants and cell phones executing operating system software such as PalmOS, WindowsCE, and the like. Moreover, the present invention is readily extended to network devices such as office equipment, vehicles, and personal communicators that make occasional connection through network **101**.

[0039] Each of the devices shown in **FIG. 1** may include memory, mass storage, and a degree of data processing capability sufficient to manage their connection to network

101. The computer program devices in accordance with the present invention are implemented in the memory of the various devices shown in **FIG. 1** and enabled by the data processing capability of the devices shown in **FIG. 1**. In addition to local memory and storage associated with each device, it is often desirable to provide one or more locations of shared storage such as disk farm (not shown) that provides mass storage capacity beyond what an individual device can efficiently use and manage. Selected components of the present invention may be stored in or implemented in shared mass storage.

[**0040**] One feature of the present invention is that front-end servers **201** (shown in **FIG. 2B**) and/or intermediate servers **206** (shown in **FIG. 2A**) are implemented as an interchangeable pool of servers, any one of which may be dynamically configured to receive request/response traffic of particular clients **205** and servers **210-212**. The embodiments of **FIG. 2**A and **FIG. 2B** are not strictly alternative as they may coexist in a network environment. A redirection mechanism, shown in **FIG. 3**, is enabled to select from an available pool of front-end servers **201** and intermediate servers **206** and direct client request packets from the originating web server to a selected front-end server **201** or intermediary server **206**.

[**0041**] In the case of web-based environments, front-end **201** is implemented using custom or off-the-shelf web server software. Front-end **201** is readily extended to support other, non-web-based protocols, however, and may support multiple protocols for varieties of client traffic. Front-end **201** processes the data traffic it receives, regardless of the protocol of that traffic, to a form suitable for transport by TMP **202** to a back-end **203**. Hence, most of the functionality implemented by front-end **201** is independent of the protocol or format of the data received from a client **205**. Hence, although the discussion of the exemplary embodiments herein relates primarily to front-end **201** implemented as a web server, it should be noted that, unless specified to the contrary, web-based traffic management and protocols are merely examples and not a limitation of the present invention.

[**0042**] In the embodiment of **FIG. 2**A, intermediary servers **206** interact directly with server(s) **210-212**. In the embodiment of **FIG. 2**B, intermediary server **206** is implemented as front-end computer **201** and a back-end computer **203**. Front-end server **201** establishes and maintains an enhanced communication channel with a back-end server **203**. In either embodiment, intermediary server **206**, front-end **201** and/or back-end **203** operate to cache response traffic flowing between a server **210-212** and a client **205**.

[**0043**] In the specific examples herein client **205** comprises a network-enabled graphical user interface such as a World Wide Web ("web") browser. However, the present invention is readily extended to client software other than conventional World Wide Web browser software. Any client application that can access a standard or proprietary user level protocol for network access is a suitable equivalent. Examples include client applications that act as front ends for file transfer protocol (FTP) services, voice over Internet protocol (VoIP) services, network news protocol (NNTP) services, multi-purpose internet mail extensions (MIME) services, post office protocol (POP) services, simple mail transfer protocol (SMTP) services, as well as Telnet services. In addition to network protocols, the client application may serve as a database management system (DBMS) in which case the client application generates query language (e.g., structured query language or "SQL") messages. In wireless appliances, a client application functions as a front-end to a wireless access protocol (WAP) service.

[**0044**] **FIG. 2B** illustrates an embodiment in which intermediary server **206** is implemented by cooperative action of a front-end computer **201** and a back-end computer **203**. Caching processes are performed by front-end **201**, back-end **203**, or both. Front-end mechanism **201** serves as an access point for client-side communications. In one example, front-end **201** comprises a computer that sits "close" to clients **205**. By "close", "topologically close" and "logically close" it is meant that the average latency associated with a connection between a client **205** and a front-end **201** is less than the average latency associated with a connection between a client **205** and servers **210-212**. Desirably, front-end computers have as fast a connection as possible to the clients **205**. For example, the fastest available connection may be implemented in point of presence (POP) of an Internet service provider (ISP) **106** used by a particular client **205**. However, the placement of the front-ends **201** can limit the number of browsers that can use them. Because of this, in some applications it may be more practical to place one front-end computer in such a way that several POPs can connect to it. Greater distance between front-end **201** and clients **205** may be desirable in some applications as this distance will allow for selection amongst a greater number front-ends **201** and thereby provide significantly different routes to a particular back-end **203**. This may offer benefits when particular routes and/or front-ends become congested or otherwise unavailable.

[**0045**] Transport mechanism **202** is implemented by cooperative actions of the front-end **201** and back-end **203**. Back-end **203** processes and directs data communication to and from server(s) **210-212**. Transport mechanism **202** communicates data packets using a proprietary protocol over the Internet infrastructure in the particular example. Hence, the present invention does not require heavy infrastructure investments and automatically benefits from improvements implemented in the general-purpose network **101**. Unlike the general-purpose Internet, front-end **201** and back-end **203** are programmably assigned to serve accesses to a particular server **210-212** at any given time.

[**0046**] It is contemplated that any number of front-end and back-end mechanisms may be implemented cooperatively to support the desired level of service required by the data server owner. The present invention implements a many-to-many mapping of front-ends to back-ends. Because the front-end to back-end mappings can by dynamically changed, a fixed hardware infrastructure can be logically reconfigured to map more or fewer front-ends to more or fewer back-ends and web sites or servers as needed.

[**0047**] A particular advantage of the architectures shown in **FIG. 2**A and **FIG. 2B** is that they are readily scaled. In accordance with the present invention, not only can the data itself be distributed, but the functionality and behavior required to implement dynamic content (e.g., dynamic web pages) is readily and dynamically ported to any of a number of intermediary computers **206** and/or front-ends **201** and/or back-ends **203**. In this manner, any number of client

machines **205** may be supported. To avoid congestion, additional front-ends **201** and/or intermediary servers **206** may be implemented or assigned to particular servers **210-212**. Each front-end **201** and/or intermediary server **206** is dynamically re-configurable by updating address parameters to serve particular web sites. Client traffic is dynamically directed to available front-ends **201** to provide load balancing.

[**0048**] In the examples, dynamic configuration is implemented by a front-end manager component **207** (shown only in **FIG. 2B**) that communicates with multiple front-ends **201** and/or intermediary servers **206** to provide administrative and configuration information to front-ends **201**. Each front-end **201** includes data structures for storing the configuration information, including information identifying the IP addresses of servers **210-212** to which they are currently assigned. Other administrative and configuration information stored in front-end **201** and/or intermediary servers **206** may include information for prioritizing data from and to particular clients, quality of service information, and the like.

[**0049**] Similarly, additional back-ends **203** can be assigned to a web site to handle increased traffic. Back-end manager component **209** couples to one or more back-ends **203** to provide centralized administration and configuration service. Back-ends **203** include data structures to hold current configuration state, quality of service information and the like. In the particular examples front-end manager **207** and back-end manager **209** serve multiple servers **210-212** and so are able to manipulate the number of front-ends and back-ends assigned to a particular server (e.g., server **210**) by updating this configuration information. When the congestion for the server **210** subsides, the front-end **201**, back-end **203**, and/or intermediary server **206** may be reassigned to other, busier servers. These and similar modifications are equivalent to the specific examples illustrated herein.

[**0050**] In order for a client **205** to obtain service from a front-end **201** or intermediate server **206**, it must first be directed to a front-end **201** or intermediate server **206**. Preferably, client **205** initiates all transactions as if it were contacting the originating server **210-212**. **FIG. 3** illustrates a domain name server (DNS) redirection mechanism that illustrates how a client **205** is connected to a front-end **201**. The DNS systems is defined in a variety of Internet Engineering Task Force (IETF) documents such as RFC0883, RFC 1034 and RFC 1035 which are incorporated by reference herein. In a typical environment, a client **205** executes a browser **301**, TCP/IP stack **303**, and a resolver **305**. For reasons of performance and packaging, browser **301**, TCP/IP stack **303** and resolver **305** are often grouped together as routines within a single software product.

[**0051**] Browser **301** functions as a graphical user interface to implement user input/output (I/O) through monitor **311** and associated keyboard, mouse, or other user input device (not shown). Browser **301** is usually used as an interface for web-based applications, but may also be used as an interface for other applications such as email and network news, as well as special-purpose applications such as database access, telephony, and the like. Alternatively, a special-purpose user interface may be substituted for the more general-purpose browser **301** to handle a particular application.

[**0052**] TCP/IP stack **303** communicates with browser **301** to convert data between formats suitable for browser **301** and IP format suitable for Internet traffic. TCP/IP stack also implements a TCP protocol that manages transmission of packets between client **205** and an Internet service provider (ISP) or equivalent access point. IP protocol requires that each data packet include, among other things, an IP address identifying a destination node. In current implementations the IP address comprises a 32-bit value that identifies a particular Internet node. Non-IP networks have similar node addressing mechanisms. To provide a more user-friendly addressing system, the Internet implements a system of domain name servers that map alpha-numeric domain names to specific IP addresses. This system enables a name space that is more consistent reference between nodes on the Internet and avoids the need for users to know network identifiers, addresses, routes and similar information in order to make a connection.

[**0053**] The domain name service is implemented as a distributed database managed by domain name servers (DNSs) **307** such as DNS_A, DNS_B and DNS_C shown in **FIG. 3**. Each DNS relies on <domain name:IP> address mapping data stored in master files scattered through the hosts that use the domain system. These master files are updated by local system administrators. Master files typically comprise text files that are read by a local name server, and hence become available through the name servers **307** to users of the domain system.

[**0054**] The user programs (e.g., clients **205**) access name servers through standard programs such as resolver **305**. Resolver **305** includes an address of a DNS **307** that serves as a primary name server. When presented with a reference to a domain name for a data server **210-212**, resolver **305** sends a request to the primary DNS (e.g., DNS_A in **FIG. 3**). The primary DNS **307** returns either the IP address mapped to that domain name, a reference to another DNS **307** which has the mapping information (e.g., DNS_B in **FIG. 3**), or a partial IP address together with a reference to another DNS that has more IP address information. Any number of DNS-to-DNS references may be required to completely determine the IP address mapping.

[**0055**] In this manner, the resolver **305** becomes aware of the IP address mapping which is supplied to TCP/IP component **303**. Client **205** may cache the IP address mapping for future use. TCP/IP component **303** uses the mapping to supply the correct IP address in packets directed to a particular domain name so that reference to the DNS system need only occur once.

[**0056**] In accordance with the present invention, at least one DNS server **307** is owned and controlled by system components of the present invention. When a user accesses a network resource (e.g., a database), browser **301** contacts the public DNS system to resolve the requested domain name into its related IP address in a conventional manner. In a first embodiment, the public DNS performs a conventional DNS resolution directing the browser to an originating server **210-212** and server **210-212** performs a redirection of the browser to the system owned DNS server (i.e., DNC_C in **FIG. 3**). In a second embodiment, domain:address mappings within the DNS system are modified such that resolution of the originating server's domain automatically return the address of the system-owned DNS server

(DNS_C). Once a browser is redirected to the system-owned DNS server, it begins a process of further redirecting the browser **301** to the best available front-end **201**.

[**0057**] Unlike a conventional DNS server, however, the system-owned DNS_C in **FIG. 3** receives domain:address mapping information from a redirector component **309**. Redirector **309** is in communication with front-end manager **207** and back-end manager **209** to obtain information on current front-end and back-end assignments to a particular server **210**. A conventional DNS is intended to be updated infrequently by reference to its associated master file. In contrast, the master file associated with DNS_C is dynamically updated by redirector **309** to reflect current assignment of front-end **201** and back-end **203**. In operation, a reference to data server **210-212** may result in an IP address returned from DNS_C that points to any selected front-end **201** that is currently assigned to data server **210-212**. Likewise, data server **210-212** can identify a currently assigned back-end **203** by direct or indirect reference to DNS_C.

[**0058**] Despite the efficiency of the mechanisms shown in **FIG. 3**, redirection does take some time and it is preferable to send subsequent requests for a particular server **210-212** directly to an assigned front-end **201** or intermediary server **206** without redirection. When a web page includes links with absolute references the browser **301** may attempt DNS resolution each time a link is followed. To prevent this, one embodiment of the present invention rewrites these links as a part of its reformatting process. In this manner, even though the server contains only a page with absolute references, the page delivered to a client contains relative references.

[**0059**] **FIG. 4A** illustrates a first embodiment in which a single intermediary computer **206** is used, whereas **FIG. 4**B and **FIG. 5** illustrate a second embodiment where both front-end **201** and back-end **203** are used to implement the intermediary server **206**. In the embodiment of **FIG. 4**A, the intermediary server **206** may be located topologically near the client **205** or data server **210-212**—either alternative provides some advantage and the choice of location is made to meet the needs of a particular application. Like identified components are substantially equivalent in **FIG. 4**A, **FIG. 4**B and **FIG. 5** and for ease of understanding are not duplicatively described herein. Also, the components shown in **FIG. 4**A and **FIG. 4B** are optimized for web-based applications. Appropriate changes to the components and protocols are made to adapt the specific examples to other protocols and data types.

[**0060**] Requests from client **205** are received by a TCP unit **401**. TCP component **401** includes devices for implementing physical connection layer and Internet protocol (IP) layer functionality. Current IP standards are described in IETF documents RFC0791, RFC0950, RFC0919, RFC0922, RFC792, RFC1112 that are incorporated by reference herein. For ease of description and understanding, these mechanisms are not described in great detail herein. Where protocols other than TCP/IP are used to couple to a client **205**, TCP component **401** is replaced or augmented with an appropriate network protocol process.

[**0061**] TCP component **401** communicates TCP packets with one or more clients **205**. Preferably, TCP component **401** creates a socket for each request, and returns a received response through the same socket. Received packets are coupled to parser **402** where the Internet protocol (or equivalent) information is extracted. TCP is described in IETF RFC0793 which is incorporated herein by reference. Each TCP packet includes header information that indicates addressing and control variables, and a payload portion that holds the user-level data being transported by the TCP packet. The user-level data in the payload portion typically comprises a user-level network protocol datagram.

[**0062**] Parser **402** analyzes the payload portion of the TCP packet. In the examples herein, HTTP is employed as the user-level protocol because of its widespread use and the advantage that currently available browser software is able to readily use the HTTP protocol. In this case, parser **402** comprises an HTTP parser. More generally, parser **402** can be implemented as any parser-type logic implemented in hardware or software for interpreting the contents of the payload portion. Parser **402** may implement file transfer protocol (FTP), mail protocols such as simple mail transport protocol (SMTP), structured query language (SQL), and the like. Any user-level protocol, including proprietary protocols, may be implemented within the present invention using appropriate modification of parser **402**.

[**0063**] In accordance with the present invention, intermediary **206** and front-end **201** include a caching mechanism **403**. Cache **403** may be implemented as a passive cache that stores frequently and/or recently accessed content such as pages or page elements. Cache **403** can also be implemented as an active cache that stores content according to specified rules including pages and/or page elements that have not been requested but that are anticipated to be accessed.

[**0064**] Upon receipt of a TCP packet, HTTP parser **402** determines if the packet is making a request for content within cache **403**. If the request can be satisfied from cache **403**, the data is supplied directly without reference to server **210-212** (i.e., a cache hit). Cache **403** implements any of a range of management functions for maintaining fresh content. For example, cache **403** may invalidate portions of the cached content after an expiration period specified with the cached data or by sever **210-212**. Also, cache **403** may proactively update expired cache contents before a request is received for particularly important or frequently used data from data server **210-212** by requesting updated files from the back-end **203** and/or web server **210-212**. Further, cache **403** may be proactively served with updated files(s) by back-end **203** and/or web server **210-212**. Cache **403** evicts information using any desired algorithm such as least recently used, least frequently used, first in/first out, or random eviction. When the requested data is not within cache **403**, a request is passed to server **210-212**, and the returned data may be stored in cache **403**. Some requests must be supplied to server **210-212** (e.g., customer credit information, form data and the like).

[**0065**] Although the present invention may use conventional cache instructions provided in HTTP headers, preferably the content includes caching parameters that provides independent instruction to the caching system of the present invention. In a particular example, each content element of a web site is associated with a data structure that specifies a cache expiration date value and a cache update interval value. The expiration date value indicates a specific date that the associated content element will expire. The date can be represented, for example, in seconds since Jan. 1, 1970. This

member will be zero by default. The update interval value indicates a time interval before the associate content will expire. The interval is expressed in seconds and has a zero value by default in the particular example.

[0066] Because the invention provides for passing cache instructions that are independent of any instructions in the HTTP header, the caches of the present invention may provide caching services even where the content is marked uncacheable in the HTTP header, or where the cache interval or expiration values associated with a particular piece of content differ from that specified in the HTTP header. Moreover, the present invention is readily extensible to non-HTTP protocols and languages that do not explicitly provide for any cache behavior such as, for example, FTP, structured query language (SQL), mail protocols and the like.

[0067] In response to a cached content element passing its expiration date or expiration interval, the content may either be removed from the cache or updated by reference to an origin server or other cache that has fresher content. This update can be scheduled immediately or delayed to a more convenient time (e.g. when traffic volume is low).

[0068] Preferably, the cache contents are determinable by the site owner by allowing the site owner to cause the cache to be loaded with desired content. Several mechanisms are available to implement this functionality. In one alternative, front-end manager can explicitly load content into cache **403** as desired by a site owner. In another alternative, the cache instructions passed with a response packet may indicate subsequent material to be added to cache **403**. For example, when an HTML page is loaded the cache instructions may indicate that all linked resources referenced in the HTML page should be loaded into cache **403**. In a more aggressive example, when any one page of a web site **210-212** is loaded, the entire web site is transferred to cache **403** while the user views the first accessed web page. In yet another example, cache contents are propagated by a back-end **203** to connected front-ends **201** based upon propagation rules stored and implemented by back-end **203**. For example, when the load on a back-end **203** is high and/or the resources of a back-end **203** become limited, the back-end can more aggressively or speculatively move content out to front-ends **201** to prevent hits. These cache functions may occur as a result of explicit cache instructions, or may be automatically performed by front-end **201** and/or intermediary **206** based on rules (e.g., site owner specified rules) stored in the server.

[0069] Caching can be performed on a file basis, block basis, or any other unit of data regardless of its size. Irrespective of the size of the data unit in cache, cache content is kept current by, for example, causing the front-end **201** or intermediary server **206** to check cache contents against a standard, such as a version of the data unit that is maintained in origin server **210**. When a difference between the cached data unit and the standard is detected, the cached unit may be updated by copying the changed data unit, or changed portion of the data unit, from the standard to cache **403**. By updating only changed material, rather than updating based upon fixed or static expiration times, data transfers may be lessened in frequency and quantity, especially for slow changing data.

[0070] Although back-end cache **503** is discussed below with reference to **FIG. 5**, it is important to note that any of the cache loading operations described above for cache **403** may be implemented using back-end cache **503**. For example, when a user accesses a first page of a web site, some or all of the web site may be loaded into back-end cache **503** rather than cache **403**. As front-end cache **403** will typically contain content from multiple web sites, it may be burdensome to load cache **403** immediately. Instead, content can be pushed out from cache **503** to cache **403** over time as the user continues to access the web site. In this manner, a web site owner can explicitly prevent hits to the central server(s) by proactively sending content to the various levels of cache. Similarly, either cache may proactively or speculatively fill its cache by generating requests to server **210**

[0071] The default home page or "index.html" page of the web site (i.e., the page most likely to be the first contact with a user) may be cached on the intermediary or until the website provides an updated index page permanently. A hit to the index page will result in serving the index page from the cache, and a request from the intermediary server to load the all or part of the site into the cache **403** while the user views the index.html page.

[0072] In the case of intermediary server **206**, a request that cannot be satisfied from cache **403** is generally passed to transport component **409** for communication to server **210-212** over channel **411**. An alternative to this operation is to determine from cache **403** whether an overlapping request is already pending at the server **210-212** for the same content. An overlapping request refers to a request that will generate a response having at least some content elements as a request currently being served. In this circumstance, subsequently arriving requests can be queued or buffered until the first request returns from the server **210-212** and cache **403** is loaded, as the original request is likely to be responded to prior to any subsequent requests for the same information. This may offer valuable performance improvements in situations where, in a particular example, a large file, such as a multimedia file, being accessed nearly simultaneously by a number of users would only be requested once from the back-end **203** or server **210**. By "substantially simultaneously" it is meant that many requests for the same file or resource are received prior to receipt of the response from the web server **210** or back-end **203** to the original request.

[0073] In an optional implementation, caches **403** and/or **503** include an Internet cache protocol (ICP) port for connection to each other and external cache mechanisms. ICP is described in IETF RFC 2186 as a protocol and message format used for communicating between web caches to locate specific objects in neighboring caches. Essentially, one cache sends an ICP query to a set of caches within neighboring front-ends **201**, back-ends **203** and/or intermediary servers **206**. The neighboring caches **403** and **503** respond back with a "HIT" or "MISS" message indicating whether the requested content exists in the cache.

[0074] In a particular embodiment, transport component **409** implements a TCP/IP layer suitable for transport over the Internet or other IP network. Transport component **409** creates a socket connection for each request that corresponds to the socket created in transport component **401**. This arrangement enables responses to be matched to requests that generated the responses. Channel **411** is compatible

with an interface to server **210-212** which may include Ethernet, Fibre channel, or other available physical and transport layer interfaces.

[**0075**] In **FIG. 4**A, server **210-212** returns responses to transport component **409** and supplies responses to parser **402**. Parser **402** implements similar processes with the HTTP response packets as described hereinbefore with respect to request packets.

[**0076**] HTTP component **406** reassembles the response into a format suitable for use by client **205**, which in the particular examples herein comprises a web page transported as an HTTP packet. The HTTP packet is sent to transport component **401** for communication to client **205** on the socket opened when the corresponding request was received. In this manner, from the perspective of client **205**, the request has been served by originating server **210-212**.

[**0077**] In the embodiment of **FIG. 4**A and **FIG. 5**, intermediary server **206** shown in **FIG. 2**A is implemented by front-end computer **201** and back-end computer **203**. A front-end computer **201** refers to a computer located at the client side of network **101** whereas a back-end computer **203** refers to a computer located at the server side of network **101**. This arrangement enables caching to be performed at either or both computers. Hence, in addition to caching data to serve needs of clients **205** and servers **210-212**, data can be cached to help regulate transport across the communication link **202** coupling front-end **201** and back-end **203**. For example, back-end **203** can function as an active "look-ahead" cache to fill cache **503** with content from a server **210-212** aggressively according to criteria specified by the site owner, whereas front-end can cache more passively by caching only responses to actual requests. Overall performance is improved while controlling the load on TMP connection **202** and on server **210-212**.

[**0078**] Optionally, front-end **201**, back end **203**, and intermediary computer **206** implement security processes, compression processes, encryption processes and the like to condition the received data for improved transport performance and/or provide additional functionality. These processes may be implemented within any of the functional components shown in **FIG. 4**A, **FIG. 4**B and **FIG. 5** or implemented as separate functional components within front-end **201**, back-end **203** or intermediary **206**.

[**0079**] In the embodiment of **FIG. 4**B and **FIG. 5**, the front-end **201** and back-end **202** are coupled by an enhanced communication channel (e.g., TMP link **202**). Blenders **404** and **504** slice and/or coalesce the data portions of the received packets into more desirable "TMP units" that are sized for transport through the TMP mechanism **202**. The data portion of TCP packets may range in size depending on client **205** and any intervening links coupling client **205** to TCP component **401**. Moreover, where compression or other reformatting is applied, the data will vary in size depending on the reformatting processes. Data blender **404** receives information from front-end manager **207** that enables selection of a preferable TMP packet size. Alternatively, a fixed TMP packet size can be set that yields desirable performance across TMP mechanism **202**. Data blenders **404** and **504** also mark the TMP units so that they can be re-assembled at the receiving end.

[**0080**] Data blender **404** also serves as a buffer for storing packets from all clients **205** that are associated with front-end **201**. Similarly, data blender **504** buffers response packets destined for all the clients **205**. Blender **404** mixes data packets coming into front-end **201** into a cohesive stream of TMP packets sent to back-end **203** over TMP link **202**. In creating a TMP packet, blender **404** is able to pick and choose amongst the available requests so as to prioritize some requests over others. Prioritization is effected by selectively transmitting request and response data from multiple sources in an order determined by a priority value associated with the particular request and response. For purposes of the present invention, any algorithm or criteria may be used to assign a priority.

[**0081**] TMP mechanisms **405** and **505** implement the transport transport morphing protocol™ (TMP™) packets used in the system in accordance with the present invention. Transport morphing protocol and TMP are trademarks or registered trademarks of Circadence corporation in the United States and other countries. TMP is a TCP-like protocol adapted to improve performance for multiple channels operating over a single connection. Front-end TMP mechanism **405** in cooperation with a corresponding back-end TMP mechanism **505** shown in **FIG. 5** are computer processes that implement the end points or sockets of TMP link **202**. The TMP mechanism in accordance with the present invention creates and maintains a stable connection between two processes for high-speed, reliable, adaptable communication.

[**0082**] Another feature of TMP is its ability to channel numerous TCP connections through a single TMP pipe **202**. The environment in which TMP resides allows multiple TCP connections to occur at one end of the system. These TCP connections are then combined into a single TMP connection. The TMP connection is then broken down at the other end of the TMP pipe **202** in order to traffic the TCP connections to their appropriate destinations. TMP includes mechanisms to ensure that each TMP connection gets enough of the available bandwidth to accommodate the multiple TCP connections that it is carrying.

[**0083**] An advantage of TMP as compared to traditional protocols is the amount of information about the quality of the connection that a TMP connection conveys from one end to the other of a TMP pipe **202**. As often happens in a network environment, each end has a great deal of information about the characteristics of the connection in one direction, but not the other. By knowing about the connection as a whole, TMP can better take advantage of the available bandwidth.

[**0084**] In a particular example, each TMP packet includes a header portion in which some area is available for transfer of commands between a back-end **203** and a front-end **201**. For example, a "Fill_Cache" command can be defined having a parameter specifying a URL having content that is to be loaded into the cache of the recipient of the command. In this manner, a front-end **201** can explicitly cause a back-end to fill its cache with specified content without requiring the content to be forwarded over the TMP link. Similarly, a back-end **203** can send explicit cache fill instructions to a front-end **201**. Alternatively, front-end **201** and back-end **201** can communicate cache fill instructions through management components **207** and **209**. In yet another alternative, cache fill procedures can be implemented by remote procedure calls (RPCs). For example, a

back-end **203** can issue a cache fill RPC to a front-end **201** that when executed on front-end **201** will cause front-end end **201** to request the specified content even though no client request has been received. The passive caching mechanism in front-end **201** will then perform the desired cache fill operation on the returned data.

[**0085**] Although the invention has been described and illustrated with a certain degree of particularity, it is understood that the present disclosure has been made only by way of example, and that numerous changes in the combination and arrangement of parts can be resorted to by those skilled in the art without departing from the spirit and scope of the invention, as hereinafter claimed. For example, while devices supporting HTTP data traffic are used in the examples, the HTTP devices may be replaced or augmented to support other public and proprietary protocols including FTP, NNTP, SMTP, SQL and the like. In such implementations the front-end **201** and/or back end **203** are modified to implement the desired protocol. Moreover, front-end **201** and back-end **203** may support different protocols such that the front-end **201** supports, for example, HTTP traffic with a client and the back-end supports a DBMS protocol such as SQL. Such implementations not only provide the advantages of the present invention, but also enable a client to access a rich set of network resources with minimal client software.

We claim:

1. A system for caching network resources comprising:

a server having network resources stored thereon;

a client generating requests for the network resources;

an intermediary server configured to receive requests from the client and retrieve the network resources from the server;

a cache controlled by the intermediary server for caching selected network resources, wherein the cached resources include more than the requested resources and wherein at least some of the cached resources are selected both in response to the request and explicitly selected to prevent future client requests from being communicated to the server.

2. The system of claim 1 wherein the cache includes only a home page for at least one web site.

3. The system of claim 1 wherein the intermediary server comprises a front-end computer and a back-end computer.

4. The system of claim 3 wherein both the front-end computer and the back-end computer implement a cache data structure.

5. The system of claim 4 further comprising:

a first page cached on the front-end computer cache, the first page associated with a plurality of other resources, wherein the other resources are cached on the back-end computer cache.

6. The system of claim 5 wherein the association is explicit in links within the first page that point to the secondary resources.

7. The system of claim 5 wherein the association is implicit in user access patterns.

8. The system of claim 5 wherein the association is explicitly defined by the site owner.

9. The system of claim 1 wherein the cache is configured to store web pages and elements thereof.

10. The system of claim 1 wherein the cache is configured to store program constructs comprising software code, applets, scripts, active controls.

11. The system of claim 1 wherein the cache is configured to store files.

12. The system of claim 1 further comprising:

means within the intermediary server for merging a current request for network resources that are not in the cache with a prior issued pending request for the same network resources.

13. A cache system comprising:

a communication network;

a plurality of network-connected intermediary servers each having an interface for receiving client requests for network resources, each intermediary server having a cache associated therewith;

communication channels linking each intermediary server with a set of neighboring intermediary servers for exchanging cache contents amongst the intermediary servers.

14. A method for caching network data comprising:

communicating request-response traffic between two or more network-connected computing appliances;

implementing a cache coupled to the request-response traffic; and

selectively placing data from the request-response traffic into the cache at least partially based upon attributes of the client and/or server associated with the request-response traffic.

15. The method of claim 14 further comprising:

associating client attributes with the request-response traffic, the client attributes associating a relative priority with the traffic, wherein the act of selectively placing is at least partially based upon the client attribute.

16. The method of claim 14 further comprising:

associating client attributes with the request-response traffic, the client attributes associating a service level with the traffic, wherein the act of selectively placing is at least partially based upon the client attribute.

17. The method of claim 14 further comprising:

associating client attributes with the request-response traffic, the client attributes associating a service level with the traffic, wherein the act of selectively placing is at least partially based upon the a server assigned priority.

18. A cache system comprising:

a front-end server implementing a first cache and configured to receive client requests and generate responses to the client requests;

a back-end server implementing a second cache and configured to receive requests from the front-end server and generate responses to the front-end server;

an origin server having content stored thereon;

a communication channel linking the front-end server and the back-end server;

a cache management mechanism in communication with the front-end computer and the back-end computer to selectively fill the first and second caches.

19. The cache system of claim 18 wherein the cache management mechanism comprises a process within the front-end server for receiving responses to client requests and placing the received responses in the cache.

20. The cache system of claim 18 wherein the cache management mechanism comprises a process within the front-end server for generating, sua sponte, requests and placing the responses to the sua sponte requests in the cache.

21. The cache system of claim 18 wherein the cache management mechanism comprises processes for populating one cache with contents from another cache.

22. A system for caching network resources comprising:

a plurality of intermediary servers configured to receive client requests and retrieve request-specified network resources;

a cache implemented within each of the intermediary servers and configured to store selected network resources;

a resolver mechanism for supplying a network address of the intermediary server to the client applications, wherein the resolver mechanism dynamically selects a particular intermediary server from amongst the plurality of intermediary servers based at least in part on the content of each intermediary server's cache.

23. The system of claim 22 further comprising:

a redirection mechanism within a first of the intermediary servers configured to redirect a client request from the first intermediary server to a second of the intermediary servers based at least in part on the content of the first and second intermediary server's caches.

24. A cache system comprising:

a first front-end server implementing a first cache and configured to receive client requests and generate responses to the client requests;

a second front-end server implementing a second cache and configured to receive client requests and generate responses to the client requests;

an origin server having content stored thereon;

a communication channel linking the first front-end server and the second front-end server;

a cache management mechanism in communication with the first and second front-end computers to selectively fill the second cache in response to a client request received by the first front-end server.

25. The cache system of claim 24 wherein the cache management mechanism selectively updates the second cache based upon knowledge that subsequent client requests will be directed to the second front-end server.

25. The cache system of claim 24 wherein the cache management mechanism selectively updates the second cache based upon anticipation that subsequent client requests will be directed to the second front-end server.

27. A method of speculatively caching Internet content comprising:

receiving a current request for specified content;

obtaining the specified content in response to the current request; and

speculatively caching data in addition to the specified content.

28. The method of claim 27 wherein the act of speculatively caching data comprises determining data that is likely to be requested subsequent to the current request.

29. The method of claim 27 wherein the act of speculatively caching data comprises:

determining an ability for a server to respond to subsequent requests for the data; and

speculatively caching data when it is determined that the server's ability to respond to subsequent requests is less than a preselected level.

* * * * *