WEB BROWSERS

INTRODUCTION

A browser is an application that allows people to view Web pages on the World Wide Web (a term first coined by Tim Berners-Lee of CERN, Geneva), or at a local area network. The first browser, called Mosaic, was developed in 1993 at the University of Illinois, by Marc Andreessen—now at Netscape Communications Corp.—and others. This development resulted in an explosion of the popularity of the Web, and as interest mounted, other software developers created more advanced browsers. In addition to reading text, people using the latest browsers can watch video, listen to audio, and run various other applications.

The first six months of 1998 have been called the season of the browser wars. The Justice Department charged Microsoft Corp. with engaging in anti-competitive and exclusionary practices designed to maintain its monopoly in personal computer operating systems and to extend that monopoly to Internet browsing software. It affirmed, "No firm should be permitted to use its monopoly power to develop a chokehold on the browser software needed to access the Internet." The probable reason for Microsoft's fierce battle for prominence in browsers is that a technically advanced browser could pose a major threat to the company's lifeblood, Windows.

The browser is the software the PC user sees sitting atop the operating system, and as such, the browser is strategic. It can be a powerful marketing tool that helps promote websites by mentioning other locales on the Net or the placement of so-called channels that allow companies to deliver information directly to PC users. A popular browser can also act as a calling card to corporations that may be more willing to then buy the company's powerful (and lucrative) server software. Browsers also play an important role in defining standards for viewing Web content. Server software allows business to incorporate business logic to create compelling content as well as valuable information critical to business decisions.

If a software company makes the predominant browser, it could dictate the way Web developers create their content. Moreover, the Internet is a vast commercial marketplace where consumers can do everything from investing to shopping for a car, so whoever owns the "window" to the Web—the browser—could wield a lot of influence by helping direct traffic.

This article is organized as follows: The next section discusses the Web browser technology. We then focus on alternative browsers, mobile browsers, and browsers for disabled people. The following section takes a look at communication and information exchange. Then, various business models of electronic commerce are discussed. The next section touches on the issue of security. Finally, the last section summarizes issues that are at the frontiers of WWW research.

INTERNET AND THE WORLD WIDE WEB (WWW)

In 1969, the U.S. Department of Defense (DOD) initiated the ARPANET (Advanced Research Projects Agency Network) to support collaboration and information sharing among researchers working on DOD projects. In essence, the ARPANET was the origin of the Internet. For many years, scientists, engineers, and programmers used the Internet to transfer files and send or receive electronic mail. In its early years, the Internet users had to rely on text-based user interfaces and tedious commands to use distributed computing resources on the Internet. In 1989, a dramatic shift occurred when the Graphical User Interface (GUI) was developed for the Internet, and it became known as the World Wide Web or the Web. The ease of using the GUI interface to navigating information resources on the Internet eventually made the Internet or the World Wide Web a household name within a few years. A "Web browser" is software used to navigate the information on the Web (1). Recently, the number of websites on the Internet has reached a new milestone of 100,000,000. Interestingly, 50,000,000 of those sites were added in just the past two years, which points to significant growth in content in the near future. The popularity of the Web may be seen from fig. 1 and table 1 , which show that almost 400,000,000 active Web hosts exist on the Internet. Table 2 shows that users spend a significant amount of time on the Web.

Table 1. Most popular English Web Sites in Nov 2006

Rank	Website	Visitors/day
1	www.yahoo.com	284,000
2	www.msn.com	245,400
3	www.google.com	267,600
4	www.myspace.com	36,190
5	www.live.com	115,400
6	www.youtube.com	55,480
7	www.orkut.com	26,835
8	www.ebay.com	30,950
9	www.microsoft.com	57,885
10	www.blogger.com	41,985
11	www.amazon.com	28,575
12	www.google.co.uk	21,615
13	www.megaupload.com	24,140
14	www.bbc.co.uk	19,910
15	www.go.com	17,475

Web Browser Architecture

The browser is, in essence, client-side software that provides a GUI to the user and presents incoming Hypertext Markup Language (HTML) information in user comprehensible format. Information can be presented to the user in various formats ranging from text, graphics, audio, video, and so on. Some of the information might be in static format or could be updated or changed dynamically creating an impression of interactivity between the user and the Web browser. This multimedia and interactive capability coupled with the ease of use of the GUI interface of Web browsers is essentially what has made the Web so popular among lay users across the globe. Additionally,

Table 2. Average Web Usage

United States: Average Web Usage Month of September 2006	
Visits Per Person	34
Domains Visited Per Person	62
PC Time Per Person	31:38:54
Duration of a Web Page Viewed	00:00:47
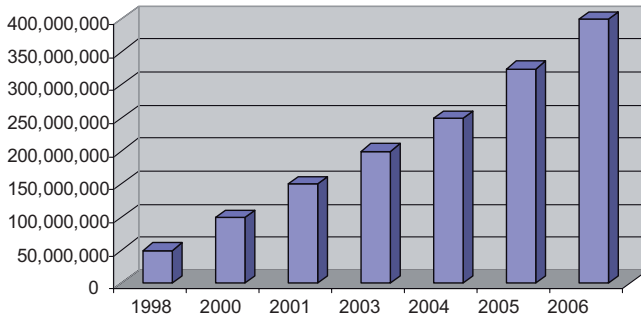
Figure 1. Internet Domain Survey Host Count

Table 3. Alternate Browsers

	Operating Systems			
Browser Name	Windows	Mac	Unix	OS/2
Amaya	Yes	No	Yes	No
Ariadna	Yes	No	No	No
Cello	Yes	No	No	No
Chimera	No	No	Yes	No
CyberDog	No	Yes	No	No
Cyberjack	Yes	No	No	No
Emissary	Yes	No	No	No
Galahad	Yes	No	No	Yes
GNUscape	Yes	Yes	Yes	Yes
I-Comm	Yes	No	No	No
InternetWorks	Yes	Yes	No	No
Lynx	Yes	Yes	Yes	Yes
MacWeb	No	Yes	No	No
MMM	No	No	Yes	No
Mozilla Firefox	Yes	No	Yes	No
Multilingual Mosaic	Yes	No	No	No
NaviPress	Yes	Yes	Yes	No
NetCruiser	Yes	Yes	No	No
Netshark	Yes	Yes	No	No
Notes Web Navigator	Yes	Yes	Yes	Yes
Omniweb	No	Yes	No	No
Opera	Yes	No	Yes	No
SeaMonkey	Yes	No	Yes	No
W3M	Yes	No	Yes	No

the cross-platform nature of Web browsers and underlying technology has made it the technology platform of choice by businesses attempting to communicate with potential customers, suppliers, employees, and stakeholders.

Web browsing uses the *client-server* paradigm (2). Conceptually, a browser consists of a set of *clients* that form the Internet access layer (3), a set of interpreters that form the presentation layer, and a controller that manages them. The browser interprets both mouse clicks and keyboard in-put and calls other components to perform operations specified by the user. For example, when a user enters a URL or clicks on a hypertext reference, the browser becomes a client that contacts a remote *Web server* on the computer specified in the URL to request the document. The browser then displays the document for the user.

The initial Web servers performed a repetitive task: they waited for a browser to open a connection and to request a specific page. The server then sent a copy of the requested page, closed the connection, and waited for the next connection. The latest Web servers perform more functions than just sending Web pages.

The Internet access layer has various protocols for communicating with remote websites. When a browser interacts with a Web server, the two generally follow the Hypertext transfer protocol (HTTP). HTTP allows a browser to request a specific item, which the server then returns. HTTP defines the exact format of requests sent from a browser to a server as well as the format of replies that the server returns, and thus ensures that browsers and servers can interoperate unambiguously. In addition to simple HTTP, other protocols support encryption.

The browser handles most of the details of document access and display. Consequently, a browser contains several large software components. Each browser must contain an HTML interpreter to display documents, which corresponds to the presentation layer that renders pages on the screen for users to enjoy. Most of the efforts in upgrading Web browsers have focused on this layer, introducing many options for fancy layout ranging from the annoying (animated GIFs) to the useful style sheets.

Input to an HTML interpreter consists of a document that conforms to HTML syntax. The interpreter translates HTML specifications into commands that are appropriate for the users' screen. For example, if it encounters a heading tag in the document, the interpreter changes the size of text used to display the heading. Similarly, if it encounters a break tag, the interpreter begins a new line of output (2).

One of the most important functions in an HTML interpreter involves selectable items. The interpreter stores information about the relationship between positions on the display and anchored items in the HTML document. When the user selects an item with the mouse, the browser uses the current cursor position and the stored position information to determine which item the user has selected.

Besides an HTTP client and an HTML interpreter, a browser can contain optional plug-ins and helper-applications, components that enable a browser to perform additional tasks. For example, many browsers include an FTP client that is used to access the file transfer service. Some browsers also contain an e-mail client that is used to send and receive e-mail messages and an RSS (remote syndication service) client that is used to access content pushed to the browser using RSS feeds.

Figure 2 illustrates the conceptual organization of a browser. Whenever a client's browser requests a page, a string of information is passed to it by the Web server. This invisible HTTP header, called a Multipurpose Internet Mail Extension (MIME) type, contains a set of instructions on how to open a specific file type, such as HTML, GIF, AVI, or MIDI. If a client's PC is configured to open that file type with the target application the MIME type defines, then the target application launches. Otherwise, the browser asks the user how to handle the file. Most Web servers are preconfigured with many common MIME types. A typical MIME statement in HTTP is of the form: Content-type: audio/midi, which implies that the file being passed is a MIDI audio file. If this statement were included in a header and the client's browser were configured to play audio/ midi files, the browser would launch a MIDI player and play the file.

Enhancements to Browser Functionality

Several developments have taken place that have been specifically focused toward making Web browsers more useful and feature-rich. The purpose is to provide more power and flexibility in using the browser to increase productivity and information presentation to the user. Several companies, including Sun Microsystems, Netscape, Microsoft, and Oracle along with other software developers such as Google, have been instrumental in these development efforts. The focus has been in making the Web browser more interactive and useful as a tool for information presentation and sharing. In most modern enterprises, data and information resides on diverse but incompatible computing platforms. Technologies such as Dynamic HTML, ActiveX, Java, JavaScript, VBScript, JavaBeans, COM, DCOM, XML, UML, web-services, and integration of Java with CORBA have been developed to fully embrace the distributed enterprise computing model supported by network interconnection gluing together these diverse platforms. The Web browser technology has the promise of cost effectively combining these diverse platforms transparently for the user to share valuable corporate data and information.

One of the important aspects of this approach is the idea of dynamic computing specifically focused on the Web browser technology to make the computing experience of the end user more effective and productive. With conventional HTML, a server process is triggered whenever the user clicks on a hyperlink, which creates additional work for the server to send and receive data packets over the network and causes the server respond to provide the requested change on the page displayed by the browser (4, 5). The system strain and the sluggishness of the server may cause response delays on the user's side.

DHTML attempts to make Web pages more interactive without requiring immediate response from the server, thereby creating a more meaningful interactivity for the user. In addition to gaining improved animation, users are able to modify a Web page on the client system without having to load anything from the host server. Usually, a host of information is downloaded from the server to the client machine running the Web browser. Only a portion of this information is displayed to the user and rest is held in the RAM (random access memory) (6). The objects on the Web page can be scripted to manipulate objects stored in RAM, thereby allowing immediate changes to the displayed information. The objects that have been displayed can be made to change appearance, such as color, position, and so on, or can be made visible or invisible, all of which can be done without having to send requests to the server every time a change is made to what is displayed on the Web page.

HTML is a simple markup language well suited for information presentation. However, it is not enough to cater to the sophisticated Internet usage and business operations carried online. Extensible Markup Language (XML) developed by W3C is capable of catering to almost all the needs of data formatting and information presentation to satisfy business transactions. Similar to HTML, XML is also a subset of SGML (Standard Generalized Markup Language).

XML allows the developer to define customized tags to support different kinds of data. As HTML is designed only for display purposes, it is extremely hard to import data back to a database or to any other application from the HTML file because the structure of the data is lost when it is only used for display purposes. XML technology promises the design of web-enabled systems that enable effortless exchange of data across the Internet, intranets, and extranets using the simple browser-based technology. Formally defined languages based on XML (such as RSS, MathML, XHTML, Scalable Vector Graphics, MusicXML, and thousands of other examples) allow diverse software reliably to understand information formatted and passed in these languages.

XML provides a means to preserve the information structure through its tags. At its base level, all information manifests as text, interspersed with markup that indicates the information's separation into a hierarchy of *character data*, container-like *elements*, and *attributes* of those elements. The XML standard is written using a subset of the Document Style Semantics and Specification Language (DSSSL). XML has many new features like bi-directional links and so on.
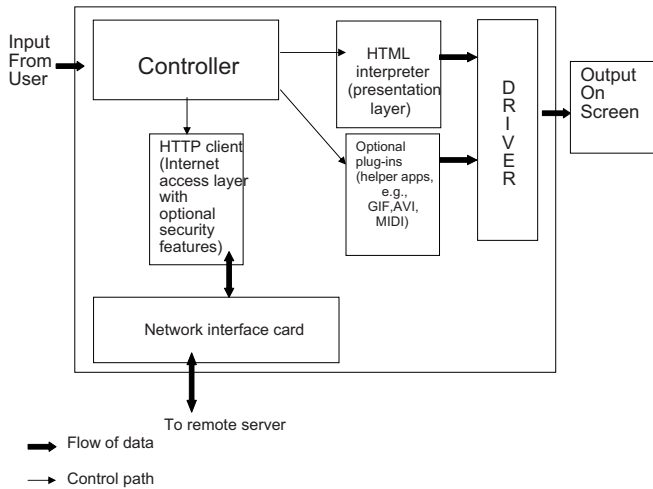
Figure 2. Browser architecture (adapted from Reference 2)

Bookmarks

Bookmarks are similar to the usual bookmark that we use while reading books. Computer bookmarks are used to remember Web pages that the user has visited. Once Web pages are bookmarked, they can be easily accessed through the menu items. This feature is available in almost all browsers. Bookmarks are called Favorites in Internet Explorer and Hotlist in Mosaic. A live bookmark is placed like an ordinary bookmark but contains a regularly updated list of links to recent articles supplied by a new site or weblog. Recently, websites such as del.icio.us have come up that allow users to save bookmarks on the Internet where they can be accessed from anywhere and can be shared and rated by other like-minded users.

Phishing Filter

The Phishing filter has been introduced as a feature in Microsoft's Internet Explorer 7. The Microsoft website (www.microsoft.com) describes Phishing as follows:

Phishing (pronounced "Fishing") is one of the fastest growing threats on the Internet and a form of identity theft. It refers to high-tech scams using phony Web sites with actual brands designed to steal valuable personal information such as user names, passwords, credit card numbers, and Social Security numbers.

The Phishing Filter Add-in offers access to a new dynamic online service, updated several times an hour, to warn you and help protect your personal information from these fraudulent Web sites by:

Scanning Web sites you visit and warning you if they are potentially suspicious.

Dynamically checking the Web sites you visit with up-to-the-hour online information via an online service run by Microsoft and blocking you from sharing personal information if a site is a known phishing Web site.

Anti-Phishing Tool Bars

The anti-Phishing tool bar is an add-on to the browsers provided by various sites. The main purpose of this tool bar is to prevent users from spoofed sites. For example, eBay provides a tool bar that identifies phished sites that are similar to eBay. The anti-Phishing tool bars have many techniques like maintaining a list of valid sites, a list of black-listed sites, using users' credit ratings, and so on to differentiate a true site from a bogus site.

Plug-ins and Helper Applications. Some software programs called plug-ins or add-ons extend the multimedia capabilities of browsers. Plug-ins enable Web page developers to add rich graphics, motion video, synchronize audio on the pages, encrypt/decrypt e-mails, play flash presentations, read or edit specific file types, and send or receive multimedia e-mails. The plug-ins use the main application for everything it needs, from registering its identity to the method it uses to communicate. Hence, plug-ins are totally dependent modules. As the main application is often created much before the plug-ins, it does not have any dependency on the plug-ins or rather it does not even know such modules will exist.

To get streaming audio and video to work, it is necessary to download the right plug-ins or helper applications, which is followed by a simple click and play on a compatible website. Audio requires a player such as RealAudio (www.realaudio.com), a real-time audio program. It uses a proprietary file format rather than standard.wav or.au files. Video streaming is video that essentially works the same way as streaming audio. Many websites including Yahoo videos, Google videos, Youtube, Disney, CNN, and ABC are already providing content. To watch the most popular video formats, such as.avi,.mov,.mp3,.mp4,.ram, and .mpg, as they download, it is necessary to have separate programs that work as plug-ins or stand-alone applications.

A technology gaining popularity allows users to subscribe to websites so that the subscribed content is automatically updated and pushed to the user's system. The XML-based technology that makes this updating possible is RSS. RSS-aware software is used to view the content.

"Feed readers" or "Aggregators" check a list of feeds on behalf of a user. If any update on the monitored items exists, the information is automatically displayed to the user. All major websites including news sites, information portals, and also numerous smaller websites provide Web feeds. Some websites allow people to choose between RSS- or Atom-formatted Web feeds; others offer only RSS or only Atom.

All popular operating systems have RSS-aware programs and many browsers have integrated support for RSS feeds. The RSS modules generally extend the XML scheme and provide a consolidated content. Many other applications exist that convert the RSS feed into a Usenet article that can be viewable through newsreader software.

ALTERNATIVE BROWSERS

One of the fall outs of the Justice Department's suit against Microsoft is the potential of alternatives to standard Netscape's Communicator and the Internet Explorer browsers. In addition, the emergence of component technology will allow third parties to build software wrappers around the Big Two's respective HTML rendering engines.

A List of Alternative Browsers

Opera. Opera Software is campaigning to establish its browser as a legitimate, cross-platform alternative to browsers from Microsoft and Netscape. At the core of this development is a vocal but seemingly significant group of Web users dissatisfied with what they call increasingly bloated browsers with features, especially heavy-overhead items like push and channel technology, that simply do not match their needs. Opera Software has developed a speedy, small-footprint (less than 2 megabytes), multi-OS browser with some unique features, including built-in zooming, support for simultaneous launching of multiple URLs, and extensive customization controls.

In some ways, Opera Software's alternative browser reminds us of the earlier efforts in 1994 by many companies like Spyglass Inc., Spry Inc., Network Computing Devices Inc., Quarterdeck Corp., and NetManage Inc. Most of these earlier groups have since either been bought up or have abandoned their browser efforts. For example, Spyglass, which was the master licensee for the original Mosaic browser code from the University of Illinois, has turned to the embeddable Web market. Among many ventures, Spyglass sells a thin browser called Device Mosaic for set-top boxes and other small-footprint devices. Spry was taken over by CompuServe. Meanwhile, other companies, such as Quarterdeck and NCD, simply refocused on strategies closer to their core strengths: Quarterdeck to PC and connectivity utilities and NCD to thin-client technology. Finally, NCSA Mosaic released its last supported browser, version 3.0, in 1997. In the end, the problem with the first generation of alternative browser companies was not their technology but their business models, according to Jim Hoffman, CEO of Bigfoot and a pioneer of the second wave of browser vendors (7).

A list of the alternative browsers appears in table 3. A few of them with names such as Opera, Amaya, and Lynx serve niche audiences of loyal users. Attachemate's Emissary, for instance, is an integrated application that provides a great deal of integration across the various IP desktop applications, such as browser, ftp client, e-mail client, and so forth.

Although the multiplicity of browsers allows innovation (fig. 3), it does become extremely confusing for Web developers. Standards do exist, but the Web is evolving faster than the World Wide Web Consortium can keep up. Developers cannot take full advantage of the features that a browser offers because what may look beautiful on one browser may not show up on another one. It is important to consider the level of support for various Internet-related standards in choosing the right set of Web applications; for example, if support for HTML frames and tables are important, the Web browser component of the desktop applications must support these features.

Micro Browser. Mobile phones, personal digital assistants (PDAs), and other similar devices have features that allow the users to browse the Web. This feature is a significant development in the handheld devices because of the benefit of being connected to the Web. Handheld devices have a browser for enabling browsing, and these specialized browsers are called micro browsers, mini browsers, or mobile browsers. The characteristics of these browsers are the ability to display the Internet content in small screens as well as the use of low bandwidth and low memory. Although micro browsers were initially developed as stripped down versions of the typical Web browser, micro browsers today have advanced features that are unique to their space.

Browsers like Netfront, Nokia Web browser, Nokia series 40 browser, Openwave, and Opera Mobile are provided by default by major mobile phone and PDA vendors. User-installable micro browsers are Opera Mini, WinWap, MobileLeap, Wapaka, PocketWeb, among others.

The Mobile application development community has standardized XHTML Basic as the language for content development and distribution, which has reduced the complexity of managing content for mobile devices, desktops, and laptops that are typically used in office or home environment. XHTML Basic is a subset of the W3C XHTML standard.

Browsers for Challenged. The traditional way of interacting with a computer using a mouse and monitor is not helpful for visually challenged people. They depend on Braille displays, keyboards, and voice recognition software. Few browsers exist that allow challenged people to access the Web. Special software and software plug-ins also allow the Web pages to be viewed using magnifiers, special screen fonts, and speech output. For example, HomePageReader, which is an IBM product that can read Web pages and provide access to multilingual text-to-speech, incorporates features like magnification and highlighting for low vision people and also supports Adobe PDF and Macromedia Flash content. The trial version of the software is available in the IBM website.

WebAdapt2Me is another IBM product that helps older people as well as people with vision, cognitive, and hand
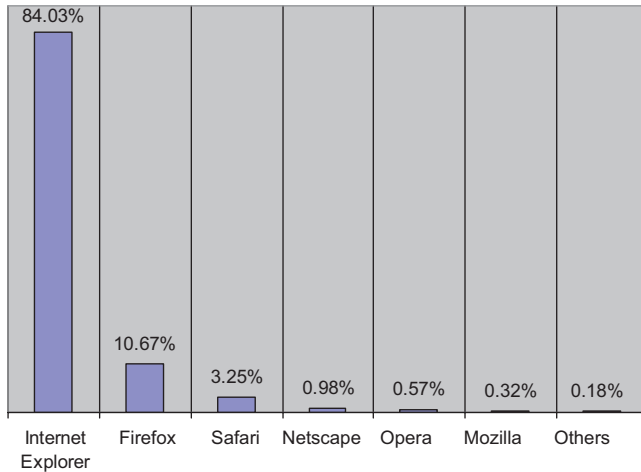
Figure 3. Browser Share as of 2006

limitations to access the Web. It includes features like magnification and speech. The preferences set by the user can be stored in a server and the user can access the Web with the same preference from any computer and from session to session. An important point to note here is that the software does not change the Web page itself but only the way it presents the information to the user.

Other similar products for people with disabilities are Braillesurf and Sensus Internet Browser.

Web-TV: An Alternative to the PC Browser

The popularity of the Web has spawned an alternative technology that can substitute for PC browsers: Web-TV. One of the aims is to provide easy access to the Web to persons who are generally uncomfortable with computers and software. Customers interested in using this technology buy a set-top box that hooks up to Web-TV (which earns revenues as the ISP) through a telephone modem. The box is an elementary computer that connects to the TV and can support peripheral devices like printers and a keyboard.

Popular Web-TV operators are MSN TV, an Internet appliance from Microsoft; Thomson TAK, a high resolution TV; and AOLTV an Internet appliance provided by AOL similar to Microsoft's MSN TV.

The term Web-TV is also used to mention the streaming video content over the Internet. Popular websites like http://videos.google.com and http://www.youtube.com provide free video content and the facility to share user's video with others. Besides, numerous subscription websites exist that offer a wide range of videos from movies to TV serials. With high bandwidth Internet connections, viewing videos on the Internet has become a pleasant experience.

Adobe Flash, Quick Time, RealNetworks, RealPlayer, SlimServer, and Winamp are some of the streaming media technologies available. HTTP, MMS, RTP, RTCP, RTSP, and RealNetworks RDT are the stream and transport protocols used.

COMMUNICATION AND INFORMATION EXCHANGE

The Internet or the World Wide Web is essentially for communication and information exchange among interested parties across the globe. The interested parties may be individual consumers searching or surfing for relevant information or businesses attempting to capture the attention of potential customers toward product or service offerings. The Internet through Web browsers provides various means of sending or receiving information both in static or dynamic format. This section discusses various means of sharing information using the Web browser.

The Internet, Intranet, and Extranet

The primary application of the browser technology can be categorized into three groups: communication over the Internet, the intranet, and the extranet.

The Internet is a network of computer networks interconnected by the TCP/IP protocol suite, which is a publicly available network where both individuals and businesses are able to share information stored on their computers across the network with interested parties. The public and global nature of this network is the most critical value-creating nature of this system.

Intranets are private Internets based on the TCP/IP protocol suite that is under the control of one or more organizations, and the information resources on the network are only shared by members of these networks. Most intranets may be connected to the Internet, but usually through firewalls and password protection so that the data on the intranets are protected from unauthorized access.

Extranets are business-to-business Internets again using TCP/IP networks that are specifically used for business-to-business information and transaction sharing (1). Extranets are controlled and secure like intranets.

Web Browsers and E-mail. In the early days, many Web browsers had built-in e-mail capability. This capability of browsers had extended the functionality of Web browsers as more comprehensive communication tools.

Recent efforts and developments in the industry to make the browser the window to almost any type of information residing on the desktop and on the Internet, intranets, and extranets points to the power of this technology as a communication tool. Among the most notable developments is the use of AJAX by Microsoft's Exchange Server and Google Mail to enable users to get almost the same user experience in accessing e-mail using Web browsers as they get with dedicated e-mail clients. Users are able to send and receive files in different formats such as word-processing files, spreadsheets, ASCII, HTML, and so on using the electronic mail client available through their Web browsers. Mozilla's Thunderbird and Microsoft's Outlook Express are example of mail clients.

The great advantage of integrating e-mail with browsers is that all of the advantages of e-mail can be accessed from anywhere in the world using a browser, especially helpful where neither party has to depend on support for asynchronous and half-duplex communication, as no need exists for an end-to-end continuous connection. Any party can send or retrieve messages independently of the other. Additionally, the integration of both the browser and the e-mail technology is a step forward toward paperless communication systems.

Linking to Enterprise Data

A useful enterprise information system is typically linked to some external data. A number of tools are available to publish data on the Web and inside discussion groups. We discuss multiple scenarios here.

> Data resides on some host-based (mainframe) application and access has to be provided via a Web browser or some other Intranet-related application.

Products such as Attachmate's Emissary Host Publishing System enable applications to be built that have HTML-like front ends, while the data still resides on host-based systems such as CICS applications and also host databases such as DB2. The product includes several of Attachmate's application-building tools such as Quick App and Quick DB, back-end TCP/IP connection to the host to move information into and out of the host, and an ActiveX custom control that generates HTML.

> People using a Web browser need access to a subset of information on an existing database server. A Web page can be designed that incorporates pieces of databases, such as showing the current status of projects, or a corporate phone directory, or a list of various forms that are available.

A number of products exist in this arena, and more are appearing almost daily. Some are gateways that connect existing SQL database servers to Web servers, so that clients using Web browsers can query the data. Others support a variety of database formats and have more extensive development environments that allow more involved forms creation and can retrieve indices of documents that are generated on the fly. One of the issues with such Web applications is that things that have long been possible in client-server systems such as data validation at the client are more difficult to implement with HTML forms.

Finally, a number of products exist that extend the office environment to include intranet awareness, includeing the ability to save files in HTML format or collaborate over the Internet using a variety of word processing and spreadsheet tools. For example, all of Microsoft's and Lotus' Office component applications have Internet features. With Microsoft Excel, a spreadsheet can be saved into a Web table format, and with Lotus' Freelance, presentations can be saved into a series of GIF files that can be viewed by browsers.

ELECTRONIC COMMERCE

The popularity of the browser front-end has resulted in applications for both the intranet and the Internet. Intranet applications include document management, online commerce, stock trading systems, mainframe access, news services, calendaring and scheduling, personal information management, contact management, inventory, procurement, data warehousing, facilities management, customer support, and technical support. Internet applications include information search, multimedia communication, electronic commerce, Web publishing, Internet communities, and personnel recruitment.

Software Purchase

Electronic commerce is likely to make a major impact on software purchases by corporate customers who face great difficulty in software selection, maintenance, and technical support.

Push technology, which allows servers to automatically broadcast updates to numerous desktops simultaneously, has also caught the attention of the IT community. When applied to software distribution, push technology enables companies to automatically send pre-subscribed data or information to a desktop Web browser at scheduled times. IT groups are using push technology to distribute software both internally and to customers, providing vendors and customers with an extremely cost-effective channel to distribute and update software.

Push Technology and Web Browsers. Finding the relevant information over the Internet usually means that the user has to take the initiative and search using available search sites such as Yahoo, Google, and so on. This type of search that is initiated by the user is known as "pull" to imply that the information is pulled by the user. On the other hand, "push" technology helps to ease the search through the vast array of information available over the Internet. The concept behind the push technology is that the information will be delivered directly to user desktops based on the preferences specified by the user, which is intended to ease both time and effort required on the part of the user to find the relevant information over the Internet. The push technology is variously known as "Netcasting" (a term coined and used by Netscape) or "Webcasting" (used by Microsoft). Although differences exist in implementa-

tion by Netscape and Microsoft of specific technology that performs the pushing of information to the user desktops, the fundamental concept and purpose have remained the same. Several companies have been using the push technology to deliver content to the users or, in some cases, subscribers. Notable among these companies are PointCast, which provides customized news or other information content to the user based on user-specified criteria. The Web browser then basically functions as a customized information delivery window.

Four basic types of push concepts have been implemented: application distributor, content aggregator, platform provider, and real-time data transfer. The application distributor is intended to help distribute software applications to user desktops, thereby making the management of software distribution and upgrading more cost effective. In this scenario, the Web browser functions as a distribution channel for software products. On the other hand, the content providers are responsible for gathering news articles and other information for end users and then distribute the collected and aggregated information to end users using the Web browser technology (8). Real-time data transfer basically deals with transfer of real-time data such as stock market data to interested parties simultaneously on a real-time basis.

Push technology has a great deal of promise, especially if combined with "artificial agent" technology so that agents would use the preferences of the user to aggregate content and deliver such content to user desktops. Most browsers have incorporated push technology in their software. The technology promises to create a new kind of broadcast medium akin to television, with information arranged on TV-style channels and passive viewing replacing interactive surfing. Instead of requiring personal computer users to search out information on the Web, the push approach lets publishers automatically deliver such features as stock quotes, news, and advertising to individual PCs.

Anecdotal evidence shows that push has historically been pushed to the sidelines. Corporate technology managers are concerned that a constant stream of downloaded data will clog their internal networks. The technology also is not easily used at home because it requires large bandwidth. However, frameworks such as Comet are reintroducing the idea of push technologies in specific applications.

SECURITY

The TCP/IP protocol was not designed with security in mind. However, as the Web develops into a major platform for commercial transactions, security on the Web has become a major concern for users and businesses. For example, when confidential documents are transmitted from a Web server to a browser, or when end users send private information back to the server inside a filled-out form, it is possible for unauthorized hackers to eavesdrop on the transaction. Browser-side risks include active content that crashes the browser, damages the user's system, breaches the user's privacy, or merely creates an annoyance. In this section, we attempt to explain the risks associated with Web browsers.

HTTP Cookies

The text file called cookie is exchanged between the server and the browser to enhance the browsing experience of the user. HTTP cookies are also known as Web cookies. Web servers identify the user based on the information stored in these cookies. The purpose of the cookie is to authenticate, track, or maintain user-specific information, browsing history specific to a site, site preferences, shopping contents, and so on. It is a common misconception that a cookie is an executable file that in itself could harm the system. In reality, it is just a text file that stores some identifying information. However, because a cookie can be used for tracking browsing behavior, it has been a concern of Internet privacy. It is possible to launch a network attack using cookies as shown by some of the following topics. Moreover, the identification based on cookies is not always accurate because the hackers use the stolen cookies to attempt fraud. An example cookie is shown below:

```
SaneID 131.247.94.252-1130512696250 americanexpress.com/
1536 2881655808 30111352 3523387728 29744082 *
```

Browser Exploits

Like any software program, browsers do come with a number of bugs and vulnerabilities. A malicious programmer could write code to exploit these vulnerabilities and cause damage to the user's system. Such code is called a browser exploit. Potential damages using this technique include installing spyware, spreading viruses, causing damage to local files, and initiating system crashes and browser crashes. Exploits can be done with HTML, JavaScript, images, ActiveX, Java, and so on. Although pure HTML code is harmless, HTML code is usually used in conjunction with malicious ActiveX or Java code to cause damage.

Cookie Grabber

A cookie can be copied from a Web page visitor to a different client. From that client, the cookie can then be used to access the webpage visitor's originally visited pages. As cookies store authentication information, the new system will be authorized to access those pages, which allows the fraud person to cause damage to the visitor. The malicious Web page script that allows the coping of cookies from one system to another is called a cookie grabber.

Browser Hijacker

When you open a browser and you find that your home page is different from what you set and you cannot reset it to the page you want, then it means that your browser is hijacked. A malware (malicious software) that resets the homepage is called a browser hijacker. Once the browser is hijacked, this software do not allow resetting the homepage to the user's wish. Upon reboot, the browser hijacker gets activated and changes the user's homepage to its intended page. The best way to remove them is through antispy software.

Cross-site Request Forgery

Cross-site request forgery works by including a link or script in a page that accesses a site to which a user is known to have authenticated. For example, user Bob might be browsing a chat forum where another user, Alice, has posted a message with an image that links to Bob's bank. Suppose that, as the URL for the image tag, Alice has crafted a URL that submits a withdrawal form on Bob's bank's website. If Bob's bank keeps his authentication information in a cookie, and if the cookie has not expired, then Bob's browser's attempt to load the image will submit the withdrawal form with his cookie, thus authorizing a transaction without Bob's approval (9).

Cross-site Scripting

A malicious script writer can inject a client-side script into a Web page. This polluted Web page, when viewed by other users, could exploit vulnerabilities like bypassing access control. This process is called cross-site scripting (XSS) and can be used to launch phishing attacks or other browser exploits.

Directory Traversal

Directory traversal is a peculiar attack in which the software is not to be blamed because the software does not have any bug. In this browser exploit, the lack of security is the culprit rather than the usual software bug. Other names for this attack include dot-dot-slash attack, directory climbing, and backtracking. The attack is done by passing the characters representing the parent directory, for example, . . /, to the file APIs. Using this dot-dot-slash, it is possible to traverse to the root directory of the system and traverse down to a specific directory or a password file (e.g., UNIX /etc/passwd).

HTTP Response Splitting

As per the HTTP standard, the header and body are separated by one or two new lines separately. An attacker can send some content to the server and make it print after the header section of its response. By this method, an attacker can set headers and split the response into many separate responses. Thus it is called HTTP response splitting.

IDN Homograph Attack

Many characters exist that look similar or have indistinguishable glyphs. For example, the character "a" in English resembles other characters in codes such as Latin and Unicode. This similarity in characters can be exploited by attackers. A malicious programmer would fool the user by providing a remote address that looks similar in appearance but actually refers to a different address. The attack using this kind of character similarity is called an internationalized domain name (IDN) homograph attack.

Internet Cesspool

The Internet cesspool represents a collection of computers that are infected by bad programs. These machines are used as zombie machines by hackers. These machines act as a resource for an attacker in developing newer attacks.

Referrer Spoofing

Many sites share their content by limiting access to requests coming from a specified set of pages. The predefined pages from where access is allowed are called referrers. If an attacker comes to know about this referrer site, then he can send crafted information along with the request from the referrer, which will allow the attacker to access unauthorized material. The technique is called referrer spoofing.

Session Poisoning

Session poisoning, Session data pollution, or Session modification uses vulnerabilities in state management. When different scripts share the same session states but the states have different meaning and usage in each of the scripts, it leads to ambiguity and race conditions. These conditions may develop because of bad programming practices like lack of proper input validation.

Spoon (Java script)

Spoon causes performance degradation. The Java script run by the browser submits many requests to the server without the user being aware of it. This self-replicating client-side script can be used to launch denial-of-service attacks on the server or hijack the user authentication to acquire access to unauthorized information.

Legal Issues

Developments in digital signature technology over the Web have been accompanied by developments in the associated laws. Some important laws related to information security are listed below.

1999 US Gramm–Leach–Bliley Act (GLBA)

Section 11 of the description of the GLBA is described by Wikipedia (www.en.wikipedia.org) as follows:

> The Financial Privacy Rule of GLBA requires financial institutions to provide each consumer with a privacy notice at the time the consumer relationship is established and annually thereafter. The privacy notice must explain the information collected about the consumer, where that information is shared, how that information is used, and how that information is protected. The notice must also identify the consumer's right to opt-out of the information being shared with unaffiliated parties per the Fair Credit Reporting Act. Should the privacy policy change at any point in time, the consumer must be notified again for acceptance. Each time the privacy notice is re-established, the consumer has the right to opt-out again. The unaffiliated parties receiving the nonpublic information are held to the acceptance terms of the consumer under the original relationship agreement. In summary, the financial privacy rule provides for a privacy policy agreement between the company and

the consumer pertaining to the protection of the consumer's personal nonpublic information.

Fair and Accurate Credit Transaction Act of 2003 (FACTA)

Section 12 at Wikipedia describes the FACTA as follows:

Under the FACTA, which was passed by Congress on December 4, 2003 as an amendment to the Fair Credit Reporting Act, consumers can request and obtain a free credit report once every twelve months from each of the three nationwide consumer credit reporting companies (Equifax, Experian and TransUnion). The following website has been set up for this:

www.annualcreditreport.com

This act also contains provisions to help reduce identity theft, such as the ability for individuals to place alerts on their credit histories if identity theft is suspected, or if deploying overseas in the military, thereby making fraudulent applications for credit more difficult.

Anti-Phishing Act of 2005

Section 13 of Wikipedia describes that Anti-Phishing Act of 2005 as follows:

In the United States, Democratic Senator Patrick Leahy introduced the *Anti-Phishing Act of 2005* on March 1, 2005. The federal anti-phishing bill proposes that criminals who create fake websites and spam bogus emails in order to defraud consumers could receive a fine of up to $250,000 and jail terms of up to five years.

Microsoft has also joined the effort to crack down on phishing. On March 31, 2005, Microsoft filed 117 federal lawsuits in the U.S. District Court for the Western District of Washington. The lawsuits accuse "John Doe" defendants of using various methods to obtain passwords and confidential information. March 2005 also saw Microsoft partner with the Australian government to teach law enforcement officials how to combat various cyber crimes, including phishing. Microsoft announced a planned further 100 lawsuits outside the U.S. in March 2006.

RESEARCH ISSUES

In this section, we attempt to summarize the major research issues as follows:

1) Browsers for the Semantic Web
2) Security features
3) Integration of information devices

Browsers for the Semantic Web

The Semantic Web is a project that intends to create a universal medium for information exchange by putting documents with computer-processable meaning (semantics) on the World Wide Web. Currently under the direction of the Web's creator, Tim Berners-Lee of the World Wide Web Consortium, the Semantic Web extends the Web through the use of standards, markup languages, and related processing tools. The Semantic Web is a vision of Web pages that are understandable by computers, so that they can search websites and perform actions in a standardized way. A computer could, for example, automatically find the nearest manicurist or book an appointment that fits a person's schedule (fig. 4).

An implementation of a Semantic Web browser is the BigBlogZoo. Over 60,000 XML feeds have been categorized as a free resource using the DMOZ schema and can be spidered. The commercial version, Media Miner, allows you to mine these feeds for information. The SIOC Project (Semantically-Interlinked Online Communities) provides methods for interconnecting discussion methods such as blogs, forums, and mailing lists to each other. The Semantic Web Ping Service is a repository indexing updates of RDF, DOAP, FOAF, and SIOC documents (refer to section 14 of www.en.wikipedia.org).

A clear indication exists that Web browsers will offer more functionality in the future than merely acting as tools or interfaces to look at information. Based on the above information, it appears that Web browsers will have intelligence built in to make more inferences from the material while navigating.

More Security Features

Although security structures and security features of browsers are much more efficient now than a decade ago, the new type of frauds like Phishing mentioned in the article demand more security. Also, as the usage of credit cards and sharing of personal information is ubiquitous, the need for security is paramount. New research is being initiated and directed toward improving security for a safe surfing experience.

Integration of All Information Devices

Information devices are devices like the PDA, Blackberry, and Smart watches that help to remember and process information. An increasing number of devices are enabled to access information on the Web. This feature, along with the wireless Internet, allows anyone to access the Web virtually from any place. It also poses a problem of emergence of numerous standards and formats. Extensive research is underway to integrate all information devices giving the user a uniform experience of Web surfing irrespective of the medium of access.

CONCLUSION

The Internet is a dynamic medium, and browser technologies have to keep pace with the developments on the Internet. As technological breakthroughs occur and new features are added by various industry groups and technology developers, these technologies will become a part of the Internet and browsers through the standardization

Trusted Softwares		
Signature	**Proof/Logic**	**Encryption**
	Ontology	
XML		**Namespaces**
URI/IRI		**Unicode**

Figure 4. Semantic Web

and adoption process of the World Wide Web Consortium (W3C). Given this flux in technology development, this article has focused on stable and some emerging technologies related to Web browsers that are likely to have a long and significant impact in our use of the Internet.

BIBLIOGRAPHY

1. Umar, A. *Application (Re) Engineering: Building Web-Based Applications and Dealing with Legacies.* Prentice Hall: New York, 1997.
2. Comer, D. E.; Droms, R. E. *Computer Networks and Internets.* Prentice Hall: New York, 1997.
3. Nielsen, 1997. [Query 1]
4. Sliwa, C. Customers Not Moved by Push. *Network World* 1997, **14**,pp XX–XX.
5. Sliwa, C. Dynamic HTML Vs. Dynamic HTML. *Network World* 1997, **14**,pp XX–XX.
6. Abualsamid, A. The Dynamic Microsoft Internet Explorer 4. *Network Computing* 1997, **8**,pp xx–xx.
7. Karpinski, 1997 [Query 2]
8. Sakagami, H.; Kamba, T.; Sugiura, A.; Koseki, Y. Effective Personalization of Push-Type Systems—Visualizing Information Freshness. *7th World References Wide Web Conference*; Australia, 1998.
9. Wikipedia. www.en.wikipedia.org.

Reading List [Query 3]

Abad Peiro, L.; Asokan, N.; Steiner, M.; Waidner, M. Designing a Generic Payment Service. *IBM Syst. J.* 1998, **37**,pp xx–xx. [Query 4]

Anonymous. Intranets. *Government Executive* 1997, **29**,pp xx–xx.

Berghel, H.Email—The Good, the Bad, and the Ugly, *Association for Comp Machinery* 1997, **40**,pp xx–xx.

Cheng, P.; Garay, J.; Herzberg, A.; Krawczyk, D. A Security Architecture for the Internet Protocol. *IBM Syst. J.* 1998, **37**,.pp xx–xx.

Core, G. Pushing Software Limits. *Software Mag.* 1997, *June*, [Query 5]pp xx–xx.

Crispen, P. *A Road Map to the Internet.* 1996.

Curme, O.; Roosevelt, J. Microsoft's Online Distribution Plans. *Information Week* 1996, **584**,p 132.

Enguix, C. F. Database Querying on the World Wide Web: UniGuide, an Object-Relational Search Engine for Australian Universities. *7th World Wide Web Conference*; Australia, 1998.

Flynn, J., Clark, B. How Java Makes Network-Centric Computing Real.Need Journal Title 1996, **42**,pp ss–ss.

Kobielus, J. XML Cooks Up No-Fuss E-Commerce. *Network World* 1998, **15**,pp ss–ss.

Leibs, S. Software for Rent. *Information Week* 1998, *May 25*,pp 83–91.

Machlis, S. Big-Name Sites Take Dynamic HTML for a Spin. *Computerworld* 1998, **32**,pp ss–ss.

Magid, L. Software Rentals Revisited. *Information Week* 1997,*Aug 18*,pp ss–ss.

Nguyen, T.; Wu, X; Sajeev, S. Object-Oriented Modeling of Multimedia Documents. *World Wide Web Conference*; Australia, 1998.

Peng, C.; Chen, S.; Chung, J.; Roy-Chowdhury, A.; Srinivasan, V. Accessing Existing Business Data from the World Wide Web. *IBM Syst. J.* 1998, **37**,pp ss–ss.

Pepe, M. Taking the Job Search to the Internet. *Computer Reseller News* 1997, *Nov 17*,pp ss–ss.

Price Waterhouse. *Technology Forecast*: 1997. Price Waterhouse World Technology Centre: Menlo Park, CA, 1997.

Swisher, K. RealNetworks Plans Technology Pact With Sun in Move. *Wall Street J.* 1998, *Jan. 26*,p B7.

Trowbridge, D. XML, the New Wowser for Browsers, *Computer Technol.* 1997, **17**,pp ss–ss.

Troyer, D.; Leune, C. J. WSDM: A User Centered Design Method for Web Sites. *7th World Wide Web Conference*;Australia, 1998.

Ung, G. M. Users Get Control of Net Software. *Computerworld* 1997, *Oct 27*,pp xx–xx.

VonKanel, J.; Givler, J.; Leiba, B.; Seqmuller, W. Internet Messaging Frameworks. *IBM Syst. J.* 1998, **37**,pp ss–ss.

Wu, K.; Yu, P.; Ballman, A. SpeedTracer: A Web Usage Mining and Analysis Tool. *IBM Syst. J.* 1998, **37**,pp ss–ss.

www.channelware.com

www.verisign.com

www.rsa.com

www.internetvalley.com

www.en.wikipedia.org

www.microsoft.com

http://www.cylab.cmu.edu/default.aspx?id=2255

http://www.w3c.org/

http://www.w3.org/Security/Faq/

http://www.telstra.com.au/info/security.html

http://home.netscape.com/eng/ssl3/draft302.txt

Wikipedia. www.en.wikipedia.org(accessed between October 1, 2006 and November 20, 2006). Sections 11–14.

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