Title: TECHNIQUES FOR DISTRIBUTING NETWORK PROVIDER DIGITAL CONTENT TO CUSTOMER PREMISES NODES

Abstract: Techniques for distributing digital content include receiving provider content over a network connection at a customer premises node located on premises of a first customer. The provider content is offered by a network service provider different from the first customer. Provider data based on the provider content is stored in non-volatile storage on the customer premises node of the first customer. It is determined whether conditions are satisfied for sending the provider content to a second customer different from the first customer. If it is determined that such conditions are satisfied, then the provider data is retrieved from the non-volatile storage, and data based on the provider data is sent over the network connection for receipt by the second customer. Thereby a customer premises node serves as a cache of provider content for other customer premises nodes on the same last mile segment or access network.

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TECHNIQUES FOR DISTRIBUTING NETWORK PROVIDER DIGITAL CONTENT TO CUSTOMER PREMISES NODES

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to distributing network provider digital content more closely to customer premises to reduce the consumption of network resources: and, in particular, to installing content servers on customer premises nodes to move content even closer to customers of that content and to consume fewer network resources, without an increase in infrastructure costs to the network service provider.

2. Description of the Related Art

Popular large digital content includes video, audio and images such as cable broadcast video (television) and audio (radio), on demand video and audio, and popular web pages. The delivery of such content to hundreds of thousands and millions of viewers consumes considerable network resources and can tax the available resources on existing network infrastructure. To reduce the load on network infrastructure, network administrators distribute popular content among several distribution centers strategically placed close to digital content consumers. This reduces the number of communication links the digital data must traverse and therefore conserves network resources. This also reduces the time between request and delivery of data. However, this also increases the cost of content storage because the same content must be stored multiple times. An advantage of this approach is that valuable content is replicated at the distribution centers and readily available for recovery from equipment failure at one or more other distribution centers.

Today, cable video networks utilize a media distribution mechanism that relies on the use of broadcasting all available channels simultaneously over different frequencies. Newer video-on-demand and IP-based video distribution systems still utilize a client-server model, whereby content is served from one or more servers in direct communication with a set-top box (STB) or personal computer (PC). Some servers utilize a multi-cast mode whereby data streams are transmitted to fewer than all customers on the network. As with cable video data, Internet traffic is often served by well-placed servers which cache recent high-demand web content. The servers are
distributed around the service provider's access network as close as reasonable to the customer equipment, while balancing the costs of maintaining the extra servers. These caches, distributed content servers, etc, push the content closer to the user which is receiving the data, yielding more efficient network utilization and faster interaction with the user.

While suitable for many purposes, the approach of moving content servers and caches closer to customer sites is that the same data is still stored and distributed multiple times. Multiple storage and distribution occurs even in the case where multicast streams are used to reduce the number of individual Ils. The extra storage involves extra hardware at one or more servers or extra servers compared to more centralized content servers.

The extra costs are likely to worsen with time. Requirements for distribution of high definition television (HDTV) signals, voice for both residential and business customers, and ever faster data services, will continue to force service providers to consider more efficient approaches for content distribution.

Based on the foregoing, there is a clear need for techniques that provide the benefits of distributed content servers without suffering all the disadvantages of prior art approaches. In particular, there is need for reducing consumption of scarce network resources of a service provider without bearing all the costs of increased storage centers.
BEIEF DESCRIPTION OF THE DRAWINGS

[0007] The present invention is illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings aid in which like reference numerals refer to similar elements and in which:

j0008] FIG. IA is a Mock diagram that illustrates a remote access network that distributes provider content, according to an embodiment;

£0009] FIG. IB is a block diagram that illustrates a portion of a Hybrid optical Fiber, Coaxial cable (HFC) access network, according to an embodiment;

[000] FIG. 2 is a flow diagram that illustrates at a high level a method for a content server on a customer premises node that distributes network provider content, according to an embodiment;

j00] FIG. 3 is a How diagram that illustrates at a high level a method for a content manager on a provider network that orchestrates content servers on customer premises nodes, according to an embodiment; and

[001 2] FIG. 4 is a block diagram that illustrates a router upon which an embodiment of the invention may be implemented.
DETAILED DESCRIPTION

[0013] Techniques are described for distributing digital content. In the following description, for the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the present invention. However, to one skilled in the art that the present invention may be practiced without these specific details, in other instances, well-known structures and devices are shown in block diagram form in order to avoid unnecessarily obscuring the present invention.

[0014] In the following, embodiments of the invention are described in the context of a digital television video content to custom premises nodes, such as personal computers (PCs) and set-top boxes (STBs), connected by a blend of optical fiber coaxial cable (HFC) access network to the public Internet of heterogeneous subnetworks. However, the invention is not limited to this context. In other embodiments, the customer premises node includes the same or other devices, such as laptop computers, cable-ready televisions, internet-ready televisions, game consoles, personal digital assistants, and cell phones, alone or in some combination. In various other embodiments, the provider content is audio, voice, images, and Web pages, game data, and application data, or some combination. Some other embodiments have other broadband access networks including Ethernet twisted pair, digital subscriber line (DSL), short range, internet (WIFI, subject to the International Klettetal and Electronics Engineers, JIFBF, standard 802.11), and metropolitan area (M-W, IEEE standard 802.16) access networks, alone or in combination.

[0015] According to various embodiments of the invention, content servers for distributing network services are deployed on customer premises nodes with a network link, a processing unit, and non-volatile storage. Many such devices are already widely deployed on current access networks. For example, in cable television networks, many residences in metropolitan and suburban areas, such devices include digital video recorders (DVRs) such as TIVO from TiVo Inc. of Laxisco, California, and video recorders offered by Comcast Coφ of Philadelphia, Penns. Using devices from Motorola Inc. of Schaumburg, Illinois, personal computers, and game consoles Main of these devices already include software to request and receive video content and store them for later use on the premises.
The content servers of the illustrated embodiments provide extra functions that cache provider content for redistribution to other devices connected to the same cable access network. In essence, each such device becomes a content cache for neighboring devices. Such caches are especially efficient for redistributing high value content to other devices on the same local area network and on the same neighborhood cable loop. Typically, the provider content is received in the normal course of presenting the content on the device, or a display unit in communication with the device. In addition, in various embodiments, these content servers store provider content (temporarily or permanently) on fixed media) specially delivered at one time for propagating at a later time in unicast or broadcast messages on one or more network segments in their neighborhood or elsewhere on the access or core network.

These content servers consume processing and storage resources on customer premises nodes that would otherwise be lightly used, and save the network provider from the cost of the hardware to provide the equivalent processing and storage resources.

2.0 NETWORK OVERVIEW

Networks of general purpose and application specific computer systems and other devices, such as personal digital assistants, cell phones and appliances, connected by external communication links are well known. The networks often include one or more network devices that facilitate the passage of information between the computer systems aid other devices. A network node is a network device or computer system or other device connected by the communication links.

Information is exchanged between network nodes according to one or more of many well known, new or still developing protocols. In this context, a protocol consists of a set of rules defining how the nodes interact with each other based on information sent over the communication links. The protocols are effective at different layers of operation within each node, from generating and receiving physical signals of various types, to selecting a link for transferring those signals, to the format of information indicated by those signals, to identifying which software application executing on a computer system sends or receives the information. The conceptually different layers of protocols for exchanging information over a network are described in the Open Systems Interconnection (OSI) Reference Model. The OSI Reference Model and Internet architecture is generally described in more detail in Section 1.1 of the reference book.
Communications between nodes are typically effected by exchanging discrete packets of data. Each packet typically comprises 1) header information associated with a particular protocol, and 2) payload information that follows the header information and contains information that may be processed independently of that particular protocol. In some protocols, the packet includes 3) trailer information following the payload and indicating the end of the payload information. The header includes information such as the source of the packet, its destination, the length of the payload, and other properties used by the protocol. Of en, the data in the payload for the particular protocol includes a header and payload for a different protocol associated with a different, usually higher layer of the OSI Reference Model. The header for a particular protocol typically indicates a type for the next protocol contained in its payload. The higher layer protocol is said to be encapsulated in the lower layer protocol. The headers included in a packet traversing multiple heterogeneous networks, such as the Internet, typically include a physical (layer 1) header, a data-link (layer 2) header, an internetwork (layer 3) header and a transport (layer 4) header, as defined by the Open Systems Interconnection (OSI) Reference Model.

The client-server model of computer process interaction is also widely known and used. According to the client-server model a client process sends a message including a request to a server process, and the server process responds by providing a service. The server process may also return a message with a response to the client process. Often the client process and server process execute on different devices, called hosts, and communicate via a network using one or more protocols for network communications. The term "server" is conventionally used to refer to the process that provides the service, or the host on which the process operates. Similarly, the term "client" is conventionally used to refer to the process that makes the request, or the host on which the process operates. As used herein, the terms "client" and "server" refer to the processes, rather than the hosts, unless otherwise clear from the context. In addition, the process performed by a server can be broken up to run as multiple processes on multiple hosts (sometimes called tiers) for reasons that include reliability, scalability, and redundancy.
FIG. 1A is a block diagram that illustrates a remote access network that distributes provider content, according to an embodiment. A computer network is a geographically distributed collection of interconnected sub-networks (e.g., sub-networks 10a, 110b, 110c, 110d collectively referenced hereinafter as sub-networks 110) for transporting data between nodes, such as computers. A local area network (LAN) 110a is an example of such a sub-network. The network’s topology is defined by an arrangement of end nodes (e.g., end nodes 120a, 120b, 120c, 120d, collectively referenced hereinafter as end nodes 120) that communicate with one another, typically through one or more intermedials network nodes, such as a router or switch, that facilitates routing data between end nodes 120 on different sub-networks. As used herein, an end node 120 is a node that is configured to originate or terminate communications over the network. In contrast, an intermediate network node facilitates the passage of data between end nodes. Intermediate network nodes depicted in FIG. 1A include customer premises edge nodes (CE) 150a, 150b, 150c, access modules 152a, 152b, and Broadband Remote Access Server (BRAS) node 154.

Four sub-networks 110 that are typically involved in remote access are depicted in FIG. 1A. Each sub-network 110 may include zero or more intermediate network nodes. A target network 110d, such as a network using the Internet Protocol (IP), is the objective for remote access by users at a remote site 102.

To access target network 110d, a LAN 110a is connected to CE 150a which serves as abride to a sub-network 110b which connects multiple sites in a neighborhood, sometimes called a ‘last mile,’ and thus sub-network 110b is labeled the last mile network 110b in FIG. 1A. In an illustrated embodiment, LAN 110a uses Ethernet infrastructure. Although the remote site 102 includes an Ethernet LAN 110a and its end nodes 120a, 120b, in other embodiments more or fewer end nodes 120 are connected to more or fewer different LANs 110 such as one or more LANs using Asynchronous Transfer Mode (ATM) infrastructure.

In some embodiments, CE is a telephone modem using acoustic frequency electronic signals over a low-bandwidth legacy telephone system. In some embodiment, CE 150a is a digital subscriber line (DSL) modem for establishing a high bandwidth DSL connection over the telephone wire network as the last mile network 110b. In some embodiments CE is a set top box (STB) that receives signals from a cable last mile.
network 110b and selects a signal to display on a television set or to record on an analog or digital video recorder. In an illustrated embodiment, CE 150a is a cable modem for establishing a high bandwidth cable connection over a coaxial cable network segment as the last mile network 110b. In other embodiments, sub-network 110b is replaced by another network with wide availability for remote sites, such as a network built on optical cable or a wireless network. In such embodiments, CE 150a is an optical modem or wireless network interface card for establishing a high bandwidth optical or wireless connection over the sub-network 110b. In an illustrated embodiment, the protocol used for communications over last mile network 110b is IP.

As described in more detail below, according to embodiments of the invention, a server for provider content, called herein a "provider-content server," 134 executes on one or more network nodes on the customer premises (called herein "customer premises nodes"), such as intermediate network node CE 150a, 150b, 150c, intermediate nodes on customer premises LAN, e.g., LAN 110a, and customer site end node, e.g., 120a, 120b. For purposes of illustration in FIG. 1A, a provider-content server 134a executes on customer premises end node 120a, provider-content server 134b executes on CE 150b, and provider-content server 134c executes on CE 120c. In other embodiments, more or fewer provider-content servers execute on more or fewer customer premises nodes.

Communications over sub-network UOb from CE 150a, 150b, 150c terminate at access module 152a. Although three CE 150a, 150b are depicted connected to sub-network 110b, in other embodiments more or fewer CE are connected to sub-network 110b. In an illustrated embodiment, access module 152a is a fiber node access module, as described further below with reference to FIG. 1B. In other embodiments, other devices serve as access module 152. For example, in some embodiments, access module 152a is a DSL Access Module (DSLAM). In still other embodiments, access module 152a is a controller for a bank of low-bandwidth modems or an optical or wireless access module.

A service provider (SP) typically maintains several access modules 152a, 152b and an access network 110c for connection to an IP target network 110d through a Broadband Remote Access Server (BRAS) node 154. In many emerging embodiments, the access network 110c uses IP as the communication protocol. In other embodiments, other protocols, such as the Asynchronous Transfer Mode (ATM) or the Multiple
Protocol Label Switching (MPLS) are used in access network 110c. In many emerging embodiments, the access network has a physical layer that is a hybrid optical fiber and coaxial cable (HFC) network. Although one access network 110c is depicted in FIG. 1A, in other embodiments more access networks connected by corresponding BRAS to target network 110d are included in remote access network 100.

[0029] The access network 110c includes provider content distribution hub 112, which is a server that is located on a host that is close to access modules 152a, 152b for storing popular content. Although one provider-content distribution hub server 112 is depicted in FIG. 1A, in other embodiments more or fewer provider-content distribution hub servers are located in access network 110c or other access networks (not shown).

[0030] According to some embodiments of the invention, the provider hub 112 includes a content manager process 132. As described in more detail below, the content manager process 132 controls or supports the operation of the provider-content servers 134 on the customer premises nodes. Although one content manager process 132 within one provider-content distribution hub server 112 on access network 110c is depicted in FIG. 1A, in other embodiments more or fewer content manager processes 132 are included within or external to one or more provider content distribution hubs 112 on access network 110c or other access networks or on target network 110d. In some embodiments, the functions ascribed to the content manager process 132, as described in more detail in a later section, are divided among different processes on the same or different nodes of access network 110c, target network 110d or some other network (not shown) available through access network 110c or target network 110d.

[0031] The service provider (SP) typically offers content that originates at head end servers on target network 110d for delivery to end nodes at customer sites, e.g., end nodes 120a, 120b on LAN H0a. For purposes of illustration, it is assumed that a head end server for particular content that contains a popular digital program or website executes on end node 120d. For example, head end node 120d is connected to a satellite antenna for receiving the popular digital program. There may be many thousands or hundreds of thousands of customers who wish to view that particular content. Based on anticipated or actual demand, the service provider determines that the particular content is popular and is requested by many customers. To avoid sending the same content repeatedly over target network 110d through BRAS 154 and access network 110c to access modules
S52a, 152b and thence to end nodes on customer premises, the service provider sends the content once to the provider content distribution hub servers, such as distribution hub server 112 located close to access modules 152a, 152b. The provider content distribution hub server 112 then uses fewer network communication resources to distribute that content to access modules 152a, 152b for customer premises nodes served by those access modules. The distribution of content to a distribution hub 112 within the service provider’s premises and facilities is a common approach currently used by service providers.

[0032] FIG. 1B is a block diagram that illustrates a portion of a Hybrid optical Fiber, Coaxial cable (HFC) access network 160, according to an embodiment. An HFC network is a telecommunication technology in which optical fiber cable and electrical conducting coaxial cable are used in different portions of a network to carry broadband content (such as video, data, and voice). Using HFC, a local cable television company installs fiber optic cable from a cable head-end distribution center to service nodes located close to access modules directly connected to business and residential users. From the access modules, the cable television company uses coaxial cable to individual businesses and homes. An advantage of HFC is that some of the characteristics of fiber optic cable (high bandwidth and low noise and interference susceptibility) can be brought close to the customer without having to replace the dense mesh of existing coaxial cable that is already installed in the last mile to the customer sites, e.g., to individual homes and businesses. Both cable television and telephone companies are using HFC in new and upgraded networks and, in some cases, sharing the same infrastructure to carry both video and voice conversations in the same system. The use of fiber optic cable for the backbone paths, e.g., in access network 110c, allows more data to be carried than coaxial cable alone and the portion with fiber optic cable is more reliable than coaxial cable.

[0033] The illustrated HFC access network 160 includes an optical fiber access network 111 serving as access network 110c, and a fiber node access module 162 serving as access module 152a. As part of the ‘last mile’ in the illustrated embodiment, a coaxial cable 163 extends from the fiber node access module 162 through the neighborhoods with individual homes and businesses. CEs in the individual homes and businesses, e.g., CEs 150a, 150b, 150c, connect to the cable 163 at tap points 164a, 164b, 164c, respectively, collectively referenced hereinafter as tap points 164. Often one or more bi-directional
amplifiers 166 are included on the cable to maintain signal amplitudes at effective levels for the extent of the cable 163. As depicted in FIG 3B, bi-directional amplifiers 166a, loop are interspersed between tap points 1Mb, 1o4a, IMc. respectiely As depicted in FIG 3B, cable 163, tap points IM, and bi-directional amplifier 160 constitute the last mile network. FIG 1A illustrates a combination of a network node device with processes and interfaces, such as routers, cable modems and cable set top boxes.

FIG 2 is a flow diagram that illustrates at a high level a method for a content server on a customer premises node that thated processes network traffic content according to an embodiment. Although steps are shown in FIG 2 and FIG 3 in a particular order for illustration, in other embodiments steps are performed in a different order or overlapping in time or are omitted or changed in some combination of ways.

FIG 3J. The method of 200 is executed by a process called a pro server-content server on a customer premises node, including customer premises edge nodes (CKI) other intermediate network nodes on customer premises, such as a node (not shown) in LAN HOa, and on one or more end nodes on customer premises, e.g., end nodes 120a, 120b. It is only required that the customer servers a node that executes the pro server-content service has a network connection to a processor, such as a central processing unit (CPU) or direct or indirect access to non-volatile storage on the same customer premises. Examples of end node devices that can support the pro server-content service include desktop and laptop personal computers, digital video recorders (DVRs) and game consoles such as the PlayStation from Sony Corporation of America of New York, New York, the GameCube of Nintendo of America of Redmond, Washington and the XBOX of Microsoft Corporation, of Redmond Washington. Slight modifications of other devices can also create platforms suitable for executing the prouder-content server.s on intermediate network devices including at customer edge devices (CHS). For example, in some such modifications, an internal or external hard disk for nonvolatile storage is added on intermediate network node devices with processes and network interfaces, such as routers, cable modems and cable set-top boxes.

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3.1 METHOD AT PROVIDER-CONTENT SERVER ON CUSTOMER PREMISES

In step 202 policy data is received that indicates how provider content is to be received and redistributed by the provider-content server. Any method may be used to receive the data, including, but not limited to predefined data stored within source code or m files stored with executable code f ‘default values’) or in Hies or a database accessible to the process, manual input either in response to prompts from the process or independently of prompts, or from data included in a message sent to the server by another server or from a client process, such as in one or more messages received from content manager 132.

In some embodiments, the policy data indicates that the provider-content server is to function as an archival site for the provider. For example, in some embodiments of the archival site function, the customer premises node receives unsolicited provider content from the service provider, and retains storage of the provider content indefinitely for responding to requests from other customer premises nodes. In many embodiments of the archival functions, the customer premises node is not authorized to delete the unsolicited provider content without a further message from the service provider or, at least; notification to the service provider of the deletion. In this way, the service provider can sail away rarely used content on one or more customer premises nodes. Because there are many customer premises nodes in communication with each service provider, a substantial amount of rarely used content can be stored at little expense to the service provider. Thus the service provider can offer more rare content than a service provider without the capacity to use customer premises nodes to store the rare data.

In some embodiments, the policy data indicates that the provider-content server is to function as a provider-seeded site for provider content that is to be later distributed to one or more customer premises nodes that may or may not request the provider content. For example, in some embodiments of the seeded site function, the customer premises node receives unsolicited provider content from the service provider, and retains storage of the provider content for unsolicited distribution to other customer premises nodes at a particular time. In this way a pre-recorded broadcast can be seeded to one customer premises node on each last mile segment of a HFC access network as background traffic over many hours before a scheduled broadcast. At the appointed time,
the customer premises nodes broadcast the content to their last mile segment, whereupon that content reaches all the other customer premises edge nodes that tap into the same cable, e.g., Cbs 150a, 150b, 150c tapped into cable 163. In some embodiments, to protect uiaulhorred distribution before the appointed time, the content is encrypted and the decryption key is distributed at the appointed time. Thus the consumption of network resources is greatly reduced at the time of the broadcast, when otherwise network traffic on access network 110c between distribution hub 112 and access modules 152 would be heavy. In some embodiments, during staggered broadcasts, such as broadcasts based on time zones of receivers, the content is seeded during the earlier broadcast for the receivers of the later broadcast. In some embodiments, pre-ordered data is used to determine which customer premises equipment to seed.

[0039] In some embodiments, the polychrome data indicates that the prouder-content sensor is to function as a demand site for the provider content. Each content that is requested by one or more customer premises nodes, for example, in some embodiments of the demand site function, the customer premises node requests the provider content for its own use, but retains storage of the provider content even after its own use for responding to requests from other customer premises nodes. In some embodiments of the demand site function, the customer premises node monitors, requests from other customer premises nodes on the same last mile network and either stores the provider content sent in response or measures the demand for prouder content already stored. The customer premises node retains storage of the most demanded provider content for responding to requests from other customer premises nodes. The customer premises node responds to such requests in a manner known in the art. For example, the customer premises node advertises the provider content it is storing and sends that content in response to requests as in peer-to-peer file sharing systems like BIT TORRtxf. 131 of Bn Torrent hie of San rancisco, California.

[0040] When storage space on the customer premises node becomes limiting, the provider content associated with the highest demand is kept and provider content with lower demand is deleted—at the discretion of the local provider-content sensor (e.g., provider-content sensor 134a) rather than at the discretion of the content manager (e.g., content manager 132).

[0041] In step 210, prouder content data is received at the provider-content sensor. The content is received either in one or more data packets directed to the provider-content...

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server or its customer premises node host, or in data packets directed to another customer premises node, which data packets are snooped by the provider-content server by virtue of the tap point (e.g., tap point T<sub>4A</sub>) on the same last mile link (e.g., cable 163) as the other customer premises node. In some embodiments, the provider content data is received with additional data that associates with the provider content data an archival flag that indicates an archival function, or an expiration date for deleting the provider content from storage, or release conditions that indicates when this content is to be redistributed to one or more other customer premises nodes, or some combination.

In step 220, it is determined whether conditions are satisfied for storing the provider content data. In some embodiments, the conditions for storing are determined by the software installed. In some embodiments, the conditions for storing are based at least in part on the policy data received in step 202.

For example, in some embodiments of the demand site function, only provider content requested by the customer premises node that hosts the provider-content server satisfies conditions for storing. In some embodiments of the demand site function, any provider content snooped on the last mile segment by the customer premises node that hosts the provider-content server satisfies conditions for storing. In some embodiments of the archival site function, unsolicited provider content directed to the customer premises node that hosts the provider-content server and marked for archival also satisfies conditions for storing. In some embodiments, the content is marked for archival by an archival flag associated with provider content received in step 210. In some embodiments of the seeding site function, unsolicited provider content directed to the customer premises node that hosts the provider-content server and including data that indicates when the content is to be redistributed also satisfies conditions for storing.

In some embodiments, step 220 includes determining whether there is storage space for the provider content. If there is sufficient storage space, the provider content still satisfies conditions for storing. If not, then storage depends on whether provider content already stored is of lesser worth than the newly received provider content. In such embodiments, step 220 includes determining whether the worth of the recently-received provider content is greater than the worth of the provider content already stored. Any method may be used to determine worth, in various embodiments, worth depends on the number of requests for the content, or the priority of the content, or the timeliness of
the content, or some other quantifiable property of the content, or some combination.
whether detected by the provider-content server or the service provider and received
along with the provider content received, or both.

If it is determined in step 220 that conditions for storing the provider content
are not satisfied, control passes to step 222 to perform normal processing. For example,
the provider content is output to a television set or computer display for presentation to a
viewer. Control then passes to step 250 to determine whether to retrieve and send any
previously recorded provider content data, described in more detail below.

If it is determined in step 220 that conditions for storing the provider content
are satisfied, control passes to step 230. In step 230, it is determined whether conditions
are satisfied for deleting provider content data previously stored. In some embodiments,
the conditions for deleting are determined by the software installed. In some
embodiments, the conditions for deleting are based at least in part on the policy data
received in step 202. For example, the conditions for deleting are based on a maximum
age provided by the policy data.

In some embodiments, it is determined during step 230 whether there is
insufficient storage space to store provider content that has higher worth than provider
content already stored. In some embodiments, it is determined during step 230, whether
an age of provider content data already stored exceeds a maximum age for storing that
data associated with the content data or dictated by policy data received in step 202. In
some embodiments, it is determined during step 230, whether a current lime follows an
expiration date associated with the content data. In some embodiments, it is determined
during step 230 whether a message is received from the service provider to delete
archived data. In some embodiments, such a message is indicated by the archival flag
associated with provider content received in step 210. In some embodiments, step 230
includes sending a request to the service provider, such as to the content manager process
132, to grant permission to delete provider content already stored at the customer
premises node that hosts the provider-content server; and receiving a response, and
determining whether to delete provider content based on the response.

If it is determined in step 230 to delete provider content data previously stored,
control then passes to step 232. In step 232, provider content data previously stored is
deleted. Control then passes to step 240 to store provider content. If it is determined in
step 230 to not delete πio\ ider content data prev iousK st red, con ltol then passes diiecth to step 240

[0049] In step 24! the pix iider content data is stored on non-volatile storage local to the customei premises node that hosts the πio\ ides-content server. The πo\ ider content data may be stored in another manner known in the art. In some embodiments, the πo\ ides content data is first compressed. In take less storage space and then the compressed data is stored. Control then passes to step 25[').

[0050] According to some embodiments, when content is recorded during step 240, the recoordiny is also adv\ i used to some “hnst sen er” or “magnet site” en\ lm that is responsible for helping other πrcn ider content sen ers locate πo\ ider content. The hnst sen er is provided by the content manager. 132 m the illustrated embodiment, as described in more detail below. In other embodiments, the list sen er is a separate sen er. For example, a cable modem let\ pimiation system (CMTS) on access module 152, or a content sen er in each neighborhood (e.g. a designated πrcn ider content server on customer premises equipment). In some embodiments, multiple list sen ers in a hierarchy store the associations between content sen ers and content. It is then possible for another customer premises πio\ ides content server to consult this list and download the hnst from its closest source. In some embodiments, the ident\ yi address of the list server is included in the πoh\ data rec\ ed dur\ sig step 202, described above.

[0051] In some embodiments, the selection of a content sen er from which to request content, such as a content sen er identified in the hnst form the list ser\ yer, depends on a quality of service that can be expected from that content sen er to the requesting node. For example, statistics of congestion and load at different content sen ers are used to estimate download πe\ p\ pance across the cable network in comparison to other sources of the content, such as the hubs, or other sources on the list. Similar to the content sen er is considered in some embodiments. More localized download are usual) for more efficient use of network resources. For example, if one site has 2 D\ Rs, and a first record? some content, then when a request is made by the other, the list indicates the content is at the server on the requestor’s local network. The request is then directed to the first DVR, which is downloaded from that DVR. and other content servers are not consumed with supp\ ing the content.
In step 250, it is determined whether conditions are satisfied for sending provider content data previously stored. In some embodiments, the conditions for sending are determined by the software installed. In some embodiments, the conditions for sending are based at least in part on the policy data received in step 202. For example, the conditions for sending include some conditions for sending a broadcast on a network segment, some conditions for sending a unicast to a particular customer premises node that requests the data, or both; and are provided by the policy data.

In some embodiments, during step 250 it is determined whether a request is snooped on last mile network through the network connection with the provider network, and whether the requested provider content resides in local storage, and whether the content provider server is to provide data to all received requests no matter where directed. For example, in some embodiments, it is determined at end node 120a executing provider-content server 134, that a request passing tap point 164a on cable 165 is sent (in both directions) from CPE 150b requesting a particular video program and that the particular video program is indeed stored locally on end node 120a and that server 134a is to respond to all requests. Therefore it is determined that conditions are satisfied for sending the particular provider content to CE 150b. Note that it is not required that CE 150b have a provider-content server 134a executing. Any conventional request for provider data can be answered by provider-content server 134a. In embodiments in which server 134 is only to respond to requests directed solely to server 134a, then conditions are not satisfied for sending the particular data based on snooping a request.

In some embodiments, during step 250 it is determined whether a request is directed to the provider-content server for particular provider content and whether the requested provider content resides in local storage and whether the content provider server is to provide data to all requests directed to the server. For example, in some embodiments, it is determined at end node 120a executing provider-content server 134a, that a request is directed to provider-content server 134a that a particular video program be sent to a particular customer premises equipment on a different last mile network than cable 163. If it is determined that the particular video program is indeed stored locally on end node 120a, then it is determined that conditions are satisfied for sending the particular provider content to CE 150h. Note that it is not required that the requesting customer premises node have a provider-content server 134 executing. Any conventional request
for provider data can be answered by provider-content server 134. In an illustrated embodiment, a content server on the requesting node utilizes a query to a list server, such as content manager 132, to determine the content server from which to request the particular content.

In some embodiments, during step 250 it is determined whether an appointed time has arrived when seeded provider content data that is stored locally is to be released. In some embodiments, during step 250 it is determined whether a decryption key has been received at the provider-content server for seeded encrypted provider content data that is stored locally.

If the particular provider content is not stored locally at provider-content server, then conditions are not satisfied for sending the provider content.

If it is determined in step 250 that conditions are not satisfied for sending provider content data, control passes back to step 210 to deal with any further provider content data that is received. If none is received in a reasonable time control passes back to step 250 to see if conditions are presently satisfied for sending provider content data.

If it is determined in step 250 that conditions are satisfied for sending provider content data, control passes to step 260. In step 260, provider data stored locally on non-volatile storage is retrieved and sent to another customer premises node. Any method may be used to send the data. In some embodiments, compressed data is retrieved and sent to the other customer premises node. In some embodiments, uncompressed data is retrieved and sent to the other customer premises node. In some embodiments, compressed data is retrieved, the uncompressed provider content data is reconstituted, and the uncompressed provider content data is sent to the other customer premises node.

In some embodiments, a message is sent to the service provider network (e.g., to provider content distribution server 112) that the request has been answered by the provider-content server 134. In response to receiving this message, the service provider does not further respond to the request. For example, the provider content distribution hub 112 receives data that indicates the provider content requested by CE 150b is being satisfied by end node 12Oa. Thus the provider content distribution hub 112 does not also respond by sending the requested provider content data.

The Data Over Cable Sen-ice Interface Specification (DOCSIS) defines interface standards for cable modems and supporting equipment. Other devices that
recognize and support DOCSIS include HDTV and web-enabled STBs for regular
television. DOCSIS specifies downstream (service provider network to CE) traffic
transfer rates between 27 and 26 million bits per second (Megabits per second, Mbps,
where a bit is a binary digit) over a radio frequency (RF) channel in the range from 50
million cycles per second (MegaHertz, MHz) to over 750 MHz. Upstream (CE to service
provider network) traffic rates lie between 0.32 Mbps and 10 Mbps over a RF channel in
the range from 5 MHz to 42 MHz.

[0064] In some embodiments, a new frequency is allocated as an extra channel for
sharing CE to CE traffic. By using the extra channel, the customer does not see the
Internet connection bandwidth affected.

[0062] In some embodiments, a broadcast over a network segment is not possible and
the content must be sent in a point to point data packet. For example, in some DSL last
mile networks, one customer premises node can not send data packets directly to another
customer premises node on the same segment. In such embodiments, the data can be sent
to the access module, e.g., a DSLAM at the end of the segment and the DSLAM can
forward the packet to the destination node. Although this causes two data packets to be
sent over the last mile, it still sacrifices traffic on the upstream access network 110c.

[0063] After step 260, control then passes back to step 210 to deal with any further
provider content data that is received. If none is received in a reasonable time control
passes back to step 250 to see if conditions are presently satisfied for sending provider
content data.

3.2 METHOD AT CONTENT MANAGER ON SERVICE PROVIDER NETWORK

[0064] In some embodiments, the provider-content servers (e.g., server 134) operate
as peers and store any data received that outranks data already in storage, as ranked by
demand or other measure of worth, and respond to all requests for data that is stored. In
some such embodiments, there is need for a content manager (e.g., content manager 132)
to function as list server that allows one peer to find another peer. In other embodiments
with content servers 134 behaving as peers, there is no need for a content manager (e.g.,
content manager 132) on the service provider network. In embodiments that include
archival and seeding functions, however, a content manager is usually involved.

[0065] FIG. 3 is a flow diagram that illustrates at a high level a method 300 for a
content manager (e.g., content manager 132) that resides in the service provider network
and that orchestrates content sets on customer premises nodes, according to an embodiment.

In step 3, content for data is recognized. A method may be used to receive the data, as described above. In one embodiment, step 302 includes receiving a file of computer instructions that sends a storage program that implements the content, including some combination of peer-to-peer demand, such as seeding functions. In some embodiments, values for certain parameter nodes are recognized during step 302. For example, the maximum age to keep stored program content data is recognized in step 302.

In step 3, data is retrieved that indicates one or more customer premises nodes that will host content server. A method may be used to recognize the host data. It is recognized that not every customer will agree to use the resources of that customer's equipment to support the distribution of program content. For example, some embodiment's customers of site 10 agrees to use node 120a as a host for the program content server at node 120b or CE 150a. The customer on whose premises content resides, may not agree to use that node to execute programs or the CE 150c may not have permanent storage and therefore not be suitable as a host for the program content server.

To address the concerns of CPU utilization and disk space, a few approaches are possible. First, a program-managed file system, such as a set-top box or modem, the customer may be unaware that this is occurring. In some embodiments, an equipment leasing contract is structured to allow pan idcr-managed CHs to be used for a program content server. Second, for non-program managed CHs such as PCs and DVRs, the user would like at least be aware that content sharing is occurring and special software would likely be installed. In some embodiments, a market-based stem of one or more incentives is offered. For example, the server program offers a faster response to customer requests if the customer agrees to share a certain amount of hard disk space. The offer is feasible, because its acceptance increases the likelihood that the customer value exceed the customer's neighbors' caching services to speed the response in some embodiments. The offer is more incentives include money.
e.g., by awarding credits for larger, more relevant caching of the provider's content for other customers.

[0069] To address the concerns of bandwidth, other approaches are possible. In some embodiments, a new DOCSIS frequency is allocated as an extra channel for sharing CE to CE traffic, as described above. In some embodiments, well known IP-based bandwidth reservation methods are used, alone or in combination with the extra DOCSIS channel.

[0070] In some embodiments, step 330 includes receiving status messages from all provider-content servers on customer nodes.

[0071] In some embodiments, the customer communicates verbally with a customer service representative of the service provider, and an administrator for the service provider manually inputs the information about the node to serve as host.

[0072] In step 320, provider-content server software is installed on the nodes determined in step 310 to be hosts. In some embodiments, the software is installed outside the control of the content manager, e.g., manually by the customer or by a customer service representative, and step 320 is omitted.

[0073] In step 322, provider-content policy data is sent to the provider-content servers on the nodes identified in step 310. Any method may be used to send this data. For example, in some embodiments, a message is sent in a broadcast or unicast to one or more provider-content servers with data that indicates values of one or more parameters that describe the caching, distribution or retention policy, or some combination, to be implemented.

[0074] In step 330, it is determined whether conditions are satisfied for archiving provider content. Any method may be used to determine whether such conditions are satisfied. In some embodiments, the content manager determines a set of content data that is rarely used and distributes that content among all available provider-content servers, with some duplication to provide protection against lost data, should an archiving node fail. If one archiving node fails, conditions are satisfied for archiving a duplicate copy of the content. In some embodiments, step 330 includes successively polling all provider-content servers on customer premises nodes to ensure that they are still functioning as an archive for their content. The polling rate can be low enough, e.g., one server per minute, so as not to burden the content manager or the provider network. In some embodiments, step 330 includes receiving status messages from all provider-content servers on customer
ptemit.es nodes to ensure that the fate stilt functioning as an archnx fot their content Srailarh. the reporting rate can be km enough, e.g., once pet week per customer premises node hosting a provider-content server so as not to burden the content manger or the pane sde network. In embodiments that do not include an archn mg function, step 330 is omitted, and control passes dueetlx to step 340

[0074] U is deteimned in step 5M that conditions are satisfied for archiving content to customer premises nodes, control passes to step 332. In step 332, the provider-content to be archiv ed is sent to one or more provider-content servers along with an archival flag that includes data that indicates the content should be archived in the local non-volatile storage for that server. Archival storage indicates that the content should be retained at the customer premises node until failure of the node or failure of the content manager, whichever comes first. Control then passes to step 310 to receive additional data indicating customer premises nodes that are joining or departing on the set of nodes that support provider-content server. If no such data is received in a reasonable time, control passes back to step 330 and following to see if conditions are satisfied for sending content to one or more provider-content servers.

[0075] In step 340, it is determined whether conditions are satisfied for seeding pto\ ider content. Any method may be used to determine whether such conditions are satisfied. In some embodiments, the content manager determines whether there are some particular pre-recorded provider content data that must be widely distributed in a small time window. Examples of such content include a broadcast television program or an opinion website to be visited in response to a broadcast. To reduce provider network congestion during that small time window, the service provider prefers to seed the content onto customer premises nodes that support a provider-content server gradualSv over a time interval that is long compared to the small time window and that occurs before the beginning of the small time window. For example, the content to be seeded on one customer premises node on each segment of the last mile network e.g., onto CPE 150b during a time interval of 24 hours long preceding the time of the broadcast. In embodiments that do not include a seeding function, step 340 is omitted, and control passes to step 350.

[0076] If it is determined in step 340 that conditions are satisfied for seeding content to customer premises nodes, control passes to step 342. In step 342, the provider content
to be seeded is sent to one or more pioduei -content sen ers along with ieiease data that
indicaes when and to whom the content should be released. Seeded storage indicates that the
content should be retained at the customer premises node until distributed and ma> be
then deleted. An combination of time and destination lor the content ma> be indicated
[0077] For example, in an illustrated embodiment, content that represents the
particuiat mouse is sent to the fast customer premisjs node that hosts a prot ider-content
sen er on each last mile cable connected to a fiber node access module, e.g., to Cb 15db
on cable 163 connected to access module 162 m H O IB within a particular tune /one
The release data in the illustrated embodiment indicates the content should be troundcast
onto cable 161 when a decrption kΩ 18 recend in such embodiments, step 342
includes sending the decryption kΩS to the same customer premises nodes at the desired
time in some embodiments, the recipients of the content are only certain subscribers, so
instead of a broadcast, the release data indicates that the content is to be sent in a
multicast or unicast onh to certain customer premises nodes, such as a list of IP addresses
on the same last mile network segment. In some embodiments, the release data indicates
that the content should be broadcast, multicast or unicast onto cable 163 at a particular
time. Control then passes to step 310 to receive additional data indicating customet
premises nodes that will recei ce the set of nodes that support pioduei -content
ses. If no such data is received in a reasonable time, control passes back to step 330
and following to see if conditions are satisfied for sending content to one or more
pioduei -content sen ers.
[0078] In step 350, it is determined whether conditions are satisfied for responding to
a request from a par ider-content sen er on a customer premises node. Any method ma>
be used to determine whether such conditions are satisfied. In an illustrated embodiment
it is determined during step 350 whether the requested content is already stored at one or
more customer premises nodes close to the requestor sian the head end (e.g., end node
120D) or a distribution hub on the pro netork (e.g., distribution hub sen er 112). In
some embodiments, step 350 is omitted, and control passes directly to step 310. And after a
reasonable time to step 330 and follow up. For example, in some embodiments, all
requests that can be answered by a prouder-wage <i> or <j> on the path from the requestor
to the content manager are answered aid the request is not forwarded or another message
is sent indicating that the request has already been answered. Therefore, all requests that

arm e unanswered at the content manager 132 are answered by a provider network distribution hub and not a provider-content server on a customer premises node. In some embodiments step 350 includes receiving a request from a provider-content server for a list of the content on customer premises nodes, or the name of a provider content server (or nearest provider content server to the requestor) from which the content can be requested.

If it is determined in step 350 that conditions are satisfied for responding to a request at a provider-content server on a customer premises node, control passes to step 352. In step 352, a response is sent for the request. For example, in some embodiments, the list of content servers' names or addresses associated with different content is sent to the requestor. In some embodiments, the request information is sent to the provider-content server that stores the requested prounder content on one of the closer customer premise nodes. The request information isispensable much less than the provider content requested and therefore forwarding the request information make a negligible impact on network resources. For example, a request from a customer premises node behind access module 152b for data stored on CE 150b is not seen and therefore not answered by CE 150b. Instead the request is forwarded from access module 152b to the network service provider, e.g., to provider content distribution hub 112. There the content manager 132 determines that the requested content is stored at CE 150b. During step 352, the content manager 132 forwards the request to provider-content server 134b on CE 150b. Provider-content server 134b then sends the content to the requesting node, as described above for step 250. The content is sent as a unicast (e.g., using IP) because a broadcast on the last mile network 110b segment does not reach the requesting node behind access module 152b. Control then passes back to step 310, and if no host data is received in a reasonable time, control passes to step 330 and following to see if conditions are satisfied for sending content to one or more prounder-content servers.

If it is determined in step 350 that conditions are not satisfied for responding to a request at a provider-content server on a customer premises node, then control passes to step 354. In step 354, a service provider network node, such as head end node 120d or distribution hub server 112, provides the content in step 354. That provider node is caused to send the content. For example, a message is sent to distribution hub server 112 to send the content to the requesting customer premises node.
To set up one or more customer premises nodes to respond to future requests for the same content, during step 354, the content manager determines whether the requesting node has a provider-content server. If so, nothing further is done by the manager 132; because, when the customer node receives the content, its provider-content server 134 will store the content provided the available space is available with lower valued content. However, if it is determined that the requesting customer node does not have a provider-content server, then the content manager determines a particular provider-content server on a customer premises node (CPN) close to the requesting node, and sends the content also to that particular provider-customer server. For example, if the content is requested by node 120b, the content manager 132 also causes the content to be sent to end node 120a that hosts provider-content server 134a.

After step 354, control then passes back to step 310, and if no host data is received in a reasonable time, control passes to step 330 and following to see if conditions are satisfied for sending content to one or more provider-content servers.

Using the methods 200 and 300 described above, the service provider causes one or more customer premises nodes to become content caches for neighboring customer premises nodes.

4.0 IMPLEMENTATION MECHANISMS -- HARDWARE OVERVIEW

FIG. 4 is a block diagram that illustrates a computer system 400 upon which an embodiment of the invention may be implemented. The preferred embodiment is implemented using one or more computer programs running on a network element such as a router device. Thus, in this embodiment, the computer system 400 is a router.

Computer system 400 includes a communication mechanism such as a bus 410 for passing information between other internal and external components of the computer system 400. Information is represented as physical signals of a measurable phenomenon, typically electric voltages, but including, in other embodiments, such phenomena as magnetic, electromagnetic, pressure, chemical, molecular atomic and quantum interactions. For example, north and south magnetic fields, or a zero and non-zero electric voltage, represent two states (0, 1) of a binary digit (bit). A sequence of binary digits constitutes digital data that is used to represent a number or code for a character. A bus 410 includes many parallel conductors of information so that information is transferred quickly among devices coupled to the bus 410. One or more processors 402
fot piocessmg information aie coupled i h the bus 410 A piocessoi 402 petfoiins a set of operations on information the set of operations include banging information in from the bus 410 and placing information on the bus 410. The set of operations altpicalh include compaing two or more units, of information, shifting position of tinint, of information and combining two or more units of information such as b\ addition oi multiplication. A sequence of operations to be executed by the piooessoi 402 constitute computeinstructions.

[0086] Computer s\ stem 400 also includes a memon 404 coupled to bus 410. The memory- that a random access memory (RAM) 01 other dynamic storage device store information including computer instructions. Dynamic memory allows a mfoimation stored therein to be changed by the computer. Stem 400 RAM allows a unit of information stored at a location called a memon address to be stored and reteNeEd independently of information at neighboring addresses. The memory 404 also used by the proeedti 402 to stoie temporan values during execution of compute instructions. The competei stem 400 includes a lead onK memories (ROM) 406 or other static storage device coupled to the bus 410 for storing static information, including instructions, that persists even when the competei stem 400 is turned off. oii tieterwise loses power.

[0087] The term computei-loadable medium is used heren to iefei to an medium that participate in pioeesing information to processot 402 including instructions (oi execution. Such a medium may take many forms, including, but not limited to, nonvolatile media volatile media and transmission media. Non-volatile media include, for example, optical or magnetic disks, such as storage de\ice 408. Volatile media include, for example, dynamic memory 404. Transmission media include, for example, coaxial cables, copper wires, fiber optic cables and waves that travel through space without wires or cables, such as acoustic waves and electromagnetic waves, including radio, optical and infrared waves. Signals that are transmitted or transmission media are termed called.

[0088] Common forms of computer-readable media include, for example, a floppy disk, a flexible disk, a hard disk, a magnetic tape or an optical magnetic medium, a
compact disk ROM (CD-ROMJ), a digital video disk (DVD) or any other optical medium, punch cards, paper tape, or any other p\(h\)s\(i\)cal med{}\(i\)ments patterns of holes, a RAM, a programmable ROM (PROM), an erasable PROM (EPROM) a FLASH-EPROM, or any other memory chip or cartridge, a modem, or a tape or any other medium from which a computer can read.

Information including instructions is provided to the bus 410 to be operated by a human user, or a sensor. A sensor detects conditions for its unit, and transforms those detection into signals compatible with the signals used to represent information in computer system 410. Other external components of terminal 412 410 that is coupled to a terminal 410, used for information interchange with humans, include a display device, such as a cathode ray tube (CRT) or a liquid crystal display (LCD) or a plasma monitor, for presenting images, and a pointing device, such as a mouse or a trackball or cursor direction keys, for controlling a position of a small cursor image presented on the display and issuing commands associated with graphical elements presented on the display of terminal 412. In some embodiments, terminal 412 is omitted.

Computers system 400 also includes one or more instances of a communications interface 470 coupled to bus 410. Communication interface 470 provides communication coupling to external devices that operate with their own processors, such as printers, scanners, external disks, and terminal 412. Firmware or software running in the computer system 400 provides a terminal interface for a character-based command interface so that external commands can be input to the computer system. For example, communication interface 470 may be a parallel port or a serial port such as an RS-232 or RS-422 interface, or an universal serial bus (USB) port on a personal computer. In some embodiments, communications interface 470 is an integrated digital network (ISDN) card or a digital subscriber line (DSL) card or a telephone modem that provides an information communication connection to a telephone line. In some embodiments, a communication interface 470 is a cable modem that connects signals on bus 410 to signals for a communication connection over a coaxial cable or optical signals for a communication connection over a fiber optic cable. As another example, communications interface 470 may be a local area network (LAN) card to provide a data communication connection to a
compatible LAN, such as Ethernet. Wireless links may also be implemented. For wireless links, the communications interface 470 sends and receives electrical, acoustic or electromagnetic signals, including infrared and optical signals, which earn information streams, such as digital data. Such signals are examples of carrier waves.

In the illustrated embodiment, special purpose hardware, such as an application specific integrated circuit (IC) 420, is coupled to bus 410. The special purpose hardware is configured to perform operations not performed by processor 402 quickly enough for special purposes. Examples of application specific ICs include graphics accelerator cards for generating images for display, cryptographic boards for encrypting and decrypting messages sent over a network, speech recognition, and interfaces to special external devices, such as robotic arms and medical scanning equipment that repeatedly perform some complex sequence of operations that are more efficiently implemented in hardware.

In the illustrated computer used as a router, the computer system 400 includes switching system 430 as special purpose hardware for switching information for flow-over a network. Switching system 430 typically includes multiple communications interfaces, such as communications interface 470, for coupling to multiple other devices. In general, each coupling is with a network link 432 that is connected to another device in or attached to a network, such as local network 480 in the illustrated embodiment, to which a variety of external devices with their own processors are connected. In some embodiments an input interface or an output interface or both are linked to each of one or more external network elements. Although three network links 432a, 432b, 432c are included in network links 432 in the illustrated embodiment, in other embodiments, more or fewer links are connected to switching system 430. Network links 432 typically provides information communication through one or more networks to other devices that use or process the information. For example, network link 432b may provide a connection through local network 480 to a host computer 482 or to equipment 484 operated by an Internet Service Provider (ISP). ISP equipment 484 in turn provides data communication services through the public, world-wide packet-switching communication network of networks now commonly referred to as the Internet 490. A computer called a server 492 connected to the Internet provides a service in response to information.
received over the Internet. For example, server 492 provides routing information for use with switching system 430.

The switching system 430 includes logic and circuitry configured to perform switching functions associated with passing information among elements of network 480. including passing information received along one network link, e.g. 432a, as output on the same or different network Sink, e.g., 432c. The switching system 430 switches information traffic arriving on an input interface to an output interface according to predetermined protocols and conventions that are well known. In some embodiments, switching system 430 includes its own processor and memory to perform some of the switching functions in software. In some embodiments, switching system 430 relies on processor 402, memory 404, ROM 406, storage 408, or some combination, to perform one or more switching functions in software. For example, switching system 430, in cooperation with processor 404 implementing a particular protocol can determine a destination of a packet of data arriving on input interface on link 432a and send it to the correct destination using output interface on link 432c. The destinations may include host 482, server 492, other terminal devices connected to local network 480 or Internet 490, or other routing and switching devices in local network 480 or Internet 490.

The invention is related to the use of computer system 400 for implementing the techniques described herein. According to one embodiment of the invention, those techniques are performed by computer system 400 in response to processor 402 executing one or more sequences of one or more instructions contained in memory 404. Such instructions, also called software and program code, may be read into memory 404 from another computer-readable medium such as storage device 408. Execution of the sequences of instructions contained in memory 404 causes processor 402 to perform the method steps described herein. In alternative embodiments, hardware, such as application specific integrated circuit 420 and circuits in switching system 430, may be used in place of or in combination with software to implement the invention. Thus, embodiments of the invention are not limited to any specific combination of hardware and software.

The signals transmitted over network link 432 and other networks through Communications interfaces such as interface 470, which carry information to and from computer system 400, are exemplary forms of carrier waves. Computer system 400 can send and receive information, including program code, through the networks 480, 490
among others, through network links 432 and communications interfaces such as interface 470. In an example using the Interact 490, a server 492 transmits program code for a particular application, requested by a message sent from computer 400, through Internet 490, ISP equipment 484, local network 480 and network link 432b through communications interface 432b. The received code may be executed by processor 402 or switching 430 as received, or may be stored in storage device 408 or other non-volatile storage for later execution, or both. In this manner, computer 430 may obtain application program code in the form of a earner \textit{\textbackslash n\textbackslash e £0096]} various forms of computer readable media may be im oh cd in cam nig one or more sequence of instructions or data or both to processor 412 for execution. For example, instructions and data may initially be earned on a magnetic disk of a remote computer such as host 482. The remote computer loads the instructions and data into its ilinie niernory and sends the instructions and data over a telephone line using a modem. A modem local to the computer may receive the instructions and data on a telephone line and uses an IR-red transmits to computer. The instructions and data to an IR-red signal, a computer wave sensing as the network link 432b. An infrared detector service communications interface in switching 430 to execute the instructions and data carried in the infrared signal and places information representing the instructions and data onto bus 410. Bus 410 carries the information to memories 404 from which processor 412 retrieves and executes the instructions using some of the data sent with the instructions. The instructions and data received in memory 404 may optionally be stored on storage device 408. Either before or after execution by the processor 402 or switching 430.

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[0097] In the foregoing specification, the invention has been described with reference to specific embodiments thereof. It will, however, be evident that various modifications and changes may be made thereto without departing from the broader spirit and scope of the invention. The specification and drawings arc, accordingly, to be regarded m an illustration either than a iestnctn e sense.

-50-
CLAIMS
What is claimed is:

i. A method for distributing digital content, comprising the steps of:
   receiving, over a network connection at a customer premises node located on
   premises of a first customer, provider digital content data offered by a
   network service provider different from the first customer, wherein the
   network service provider provides for the first customer access to a
   network of the network service provider through the network connection;
   storing provider data based on the provider digital content data in non-volatile
   storage on the customer premises node of the first customer;
   determining whether conditions are satisfied for sending the provider digital
   content data to a second customer different from the first customer; and
   if it is determined that conditions are satisfied for sending the provider digital
   content data, then
   retrieving the provider data from the non-volatile storage, and
   sending data based on the provider data over the network connection for
   receipt by the second customer.

2. A method as recited in Claim 1, said step of determining whether conditions are
   satisfied for sending the provider digital content data further comprising the step of
   determining whether a request is received from the second customer for the provider
   digital content data.

3. A method as recited in Claim 1, said step of determining whether conditions are
   satisfied for sending the provider digital content data further comprising the step of
   determining whether a request is received for the provider digital content data from a
   process of the network service provider.

4. A method as recited in Claim 1, said step of determining whether conditions are
   satisfied for sending the provider digital content data further comprising the step of
   determining whether a current date and time is not before a particular date and time
5. A method as recited in Claim 1, wherein.
the network connection communicates with a network segment lapped by multiple
customer premises nodes of multiple different customers; and
said step of sending the data based on the provider data over the network
connection for receipt by the second customer further comprising sending
the data based on provider data as one or a broadcast over the network
segment and a multicast over the network segment.

6. A method as recited in Claim 1, said step of sending the data based on the provider
data over the network connection for receipt by the second customer further comprising
sending the provider digital content as a unicast to only a second customer premises node
on premises of the second customer

7. A method as recited in Claim 1, said step of receiving provider digital content data
further comprising the steps of:
sending a request for the provider digital content data over the network
connection; and
receiving the provider digital content in response to sending the request

8. A method as recited in Claim 1, said step of receiving provider digital content data
further comprising the step of receiving provider digital content data from a premises
node on premises of a third customer different from the first customer and different from
the network service provider and different from the second customer.

9. A method as recited in Claim 1, further comprising the steps of
determining whether conditions are satisfied for deleting the provider data from
the non-volatile storage on the customer premises node; and
if it is determined that conditions are satisfied for deleting the provider data, then
deleting the provider digital content from the nonvolatile storage on the
customer premises node of the first customer.
A method as recited in Claim 9, where:

said step of receiving provider digital content further computing the step of

second an archival field that holds data that indicates whether the

provider digital content is to be archived at the customer premises node of

the first customer, and

said step of determining whether conditions are satisfied for deleting the provider data from the non-volatile storage on the customer premises node further comprises

determining whether the archival field holds data that indicates that the provider digital content is to be archived, then determining that conditions are not satisfied for deleting the provider data

A method as recited in Claim 9, where:

the method further comprises receiving additional provider digital content data

said step of determining whether conditions are satisfied for deleting the provider data from the non-volatile storage on the customer premises node further comprises the steps of

determining whether non-volatile storage on the customer premises node is insufficient for both the provider data and additional data based on the additional provider digital content data, and

if it is determined that non-volatile storage is insufficient, then

determining whether the additional provider digital content data is preferred to the provider digital content data, and

if it determined that the additional provider digital content data is preferred, then deleting the provider data from the non-volatile storage.
A method as recited in Claim 1, wherein

the method further comprises receiving, from a content managing server of the

network service provider, provider data that indicates how to determine

provider digital content data, and

said step of receiving provider digital content data further comprising receiving

provider digital content data based on the provider data,

A method as recited in Claim 1, wherein

the method further comprises receiving, from a content managing server of the

network service provider, provider data that indicates the conditions to be

satisfied for sending the provider digital content data to another customer

and

said step of determining whether conditions are satisfied for sending the provider
digital content data to the second customer is based on the provider data

A method as recited in Claim 9, wherein

the method further comprises receiving, from a content managing server of the

network service provider, provider data that indicates the conditions to be

satisfied for deleting the provider data from the non-volatile storage, and

said step of determining whether conditions are satisfied for deleting the provider
data from the non-volatile storage is based on the provider data

A method as recited in Claim 9, said step of sending data based on the provider
data over the network connection for receipt by the second customer further comprising,

sending the data based on the provider content using a dedicated channel for

communication among customer premises nodes, wherein the particular channel is not

used for receiving provider data

A method as recited in Claim 1, said step of sending data based on the provider
data over the network connection for receipt by the second customer further comprising

decrypting provider data
17. A method as recited in Claim 1, said step of storing the provider data based on the
2 provider digital content data further comprising storing compressed provider digital
3 content data.

18. A method for distributing digital content, comprising the steps of:

receiving, at a provider node on a network of a network service provider,

customer data that indicates a customer set of one or more customers,

each customer different from the network service provider, wherein the

network service provider provides access to the network for the customer

set; and

receiving host data that indicates a host set of one or more customer premises

nodes on premises of a customer subset of the customer set, wherein the

host set is available for redistributing provider content data offered by the

network service provider;

causing a content server on a first customer premises node of the host set to

perform the steps of:

caching provider content data offered by the network service; and

determining whether conditions are satisfied for sending the provider

content data to a particular customer of the customer set; and

if it is determined that conditions are satisfied for sending the provider

content data, then sending the provider content data to the

particular customer.

19. A method as recited in claim 18, said step of causing the content server on the first
2 customer premises node to perform the step of caching provider content data further
3 comprising the step of installing the content server on the first customer premises node
20. A method as recited in claim 18, wherein:

the method further comprises receiving policy data that indicates conditions for

   caching provider content data on customer premises node for the customer

   subset; and

   said step of causing the content server on the first customer premises node to

   perform the step of caching provider content data further comprising

   sending the policy data to the first customer premises node.

21. A method as recited in claim 18, wherein:

the method further comprises receiving policy data that indicates conditions for

   sending the provider content data to a particular customer of the customer

   set; and

   said step of causing the content server on the first customer premises node to

   perform the step of determining conditions for sending the provider

   content data to a particular customer further comprising sending the policy

   data to the first customer premises node.

22. A method as recited in claim 18, said caching provider content data on customer

   premises node further comprising at least one of:

   storing the provider content data for archival under control of the provider node,

   storing the provider content data seeded from the provider node under control of

   the content server; and

   storing the provider content received from second customer premises node on

   premises of a different second customer of the customer subset.

23. A method as recited in claim 18, further comprising:

   determining whether conditions are satisfied for archiving provider content on the

   first customer premises node; and

   if it is determined that conditions are satisfied for archiving provider content on

   the Inst customer premises node, then causing the provider content and an

   associated archival flag data to be sent to the content server, wherein the

   archival flag data indicates that the associated provider content is to be

   stored for archival under control of the provider node
24. A method as recited in claim 18. further comprising
determining whether conditions are satisfied for seeding provider content on the
first customer premises node, and
if it is determined that conditions are satisfied for seeding provider content on the
first customer premises node, then causing the provider content and
associated release conditions data to be sent to the content server. wherein
the release conditions data indicates how the associated provider content is
to be distributed to the particular customer

25. A method as recited in claim 19. further comprising

determining whether conditions are satisfied for responding, at the content server.
to a request for the provider content from the particular customer, and
if it is determined that conditions are satisfied for responding, at the content
server to a request for the provider content from the particular customer,
then causing the request to be sent to the content server.

26. A method as recited in claim 18, said step of receiving host data further
comprising
causing an incentive to be offered to the customer set to make customer premises
node available for distributing provider content data, and
receiving the host data in response to causing the incentive to be offered
An apparatus for distributing digital content, comprising
means for exchanging over a network connection at a customer premises node
located on premises of a first customer. Provider digital content data
offered by a network service provider different from the first customer.
wherein the network service provider provides for the first customer access
to a network of the network service provider through the network service
connection.
means for storing provider data based on the provider digital content data in non-
volatile storage on the customer premises node of the first customer.
means for determining whether conditions are satisfied (or sending the provider
digital content data to a second customer different from the first customer
and
means for relaying the provider data from the non-volatile storage and sending
data based on the provider data over the network connection for receipt by
the second customer if it is determined that conditions are satisfied for
sending the provider digital content data
An apparatus for distributing digital content, comprising
means for iecensng a l a provider node on a nehsoik ofanetwork service
pro\ider. customer data that indicates a customer set of one or mores
customoeis. each customer different from the ncm oik sen ice prn ide.
wherein the network sen ice provider proudes access to the network for
the custoniei sel,
means for recen mg host data that indicates a host set of one or more customer
premises nodes on premise* of a customer subset of the customer set,
where the host set is a\aiiable for iedistnbmiting pro\ider content data
offered bs the network service pro\ider, and
means for causing a content set to perform the steps of
set to perform the steps of
caching pro\ider content data offered bs the network service, and
determining whether conditions are satisfied for sending the pro\ider
content data to a particular customer of the customer set, and
if it is determined that conditions are satisfied for sending the pro\ider
content data, then sending the pro\ider content data to the
particular customer
A computer-readable medium can store one or more sequences of instructions for dis tributing digital content, wherein execution of the one or more sequences of instructions by one or more processors causes the one or more processors to perform the steps of: accepting a network connection at a customer premises node located on premises of a first customer, wherein the network sees the provider digital content data offered by the network service provider different from the first customer, wherein the network sees the provider digital content data for the first customer access to a network of the network service provider through the network connection. Storing the provider data based on the provider digital content data in non-volatile storage on the customer premises node of the first customer, determining other conditions are satisfied for sending the provider digital content data to a second customer different from the first customer and if it is determined that conditions are satisfied for sending the provider digital content data, then releasing the provider data from the non-volatile storage, and sending data based on the provider data over the network connection for receipt by the second customer.
30. A computer-readable medium carrying one or more sequences of instructions for distributing digital content, wherein execution of the one or more sequences of instructions by one or more processors causes the one or more processors to perform the steps of:

- receiving, at a provider node on a network of a network service provider, customer data that indicates a customer set of one or more customers, each customer different from the network service provider, wherein the network service provider provides access to the network for the customer set;

- receiving host data that indicates a host set of one or more customer premises nodes on premises of a customer subset of the customer set, wherein the host set is available for redistributing provider content data offered by the network service provider and

- causing a content server on a first customer premises node of the host set to perform the steps of:
  - caching provider content data offered by the network service; and
  - determining whether conditions are satisfied for sending the provider content data to a particular customer of the customer set; and

if it is determined that conditions are satisfied for sending the provider content data, then sending the provider content data to the partial! ar customer.
An apparatus for distributing digital content at a customer premises node located
on premises* of a first customer comprising
a network interface that is coupled to a packet switched network for
communicating through a data packet
one or more processors,
a computer-readable medium, and
one or more sequences of instructions stored in the computer-readable medium.
which, when executed by the one or more processors, cause* the one or
more processors to earn out the step of
receiving over the network interface provider digital content data offered
by a network service provider different from the first customer.
wherein the network service provider of the first
customer access to a network of the network service provider
through the network interface.
strong provider data based on the provider digital content data in non-
volatile storage on the customer premises node of the first
customer,
determining whether conditions are satisfied for sending the provider
digital content data to a second customer different from the first
customer, and
if it is determined that conditions are satisfied for sending the provider
digital content data, then
retrieving the provider data from the non-volatile storage, and
sending data based on the provider data over the network interface
for receipt by the second customer

An apparatus as recited in Claim 31, said step of determining whether conditions
are satisfied for sending the provider digital content data further comprising the step of
determining whether a request is received from the second customer for the provider
digital content data
33. An apparatus as recited in Claim 31, said step of determining whether conditions are satisfied for sending the provider digital content further comprising the step of determining whether a request is received for the provider digital content data from a process of the network service provider.

34. An apparatus as recited in Claim 31, said step of determining whether conditions are satisfied for sending the provider digital content data further comprising the step of determining whether a current date and time is not before a particular date and time

35. An apparatus as recited in Claim 31, wherein:
   the network interface communicates with a network segment tapped by multiple customer premises nodes of multiple different customers: and
   said step of sending the data based on the provider data over the network interface for receipt by the second customer further comprising sending the data based on provider data as one or a broadcast over the network segment and a multicast over the network segment.

36. An apparatus as recited in Claim 31, said step of sending the data based on the provider data over the network interface for receipt by the second customer further comprising sending the provider digital content as a unicast to only a second customer premises node on premises of the second customer.

37. An apparatus as recited in Claim 31, said step of receiving provider digital content data further comprising the steps of:
   sending a request for the provider digital content data over the network interface;
   and
   receiving the provider digital content in response to sending the request.

38. An apparatus as recited in Claim 31, said step of receiving provider digital content data further comprising the step of receiving provider digital content data from a premises node on premises of a third customer different from the first customer and different from the network service provider and different from the second customer.
39. An apparatus as recited in Claim 31, wherein execution of the one or more sequences of instructions further causes the one or more processors to perform the steps of:

- determining whether conditions are satisfied for deleting the provider data from the non-volatile storage on the customer premises node; and
- if it is determined that conditions are satisfied for deleting the provider data, then deleting the provider digital content from the non-volatile storage on the customer premises node of the first customer.

40. An apparatus as recited in Claim 39, wherein:

- said step of receiving provider digital content further comprising the step of receiving an archival field that holds data that indicates whether the provider digital content is to be archived at the customer premises node of the first customer; and
- said step of determining whether conditions are satisfied for deleting the provider data from the non-volatile storage on the customer premises node further comprises:
- determining whether the archival field holds data that indicates that the provider digital content is to be archived: and
- if it is determined that the archival field holds data that indicates that the provider digital content is to be archived, then determining that conditions are not satisfied for deleting the provider data.
41. An apparatus as recited in Claim 39, wherein:

execution of the one or more sequences of instructions further causes the one or more processors to perform the step of receiving additional provider digital content data offered by the network service provider, and

said step of determining whether conditions are satisfied for deleting the provider data from the non-volatile storage on the customer premises node further comprises the steps of

determining whether non-volatile storage on the customer premises node for the first customer is insufficient for both the provider data and additional data based on the additional provider digital content data; and

if it is determined that non-volatile storage is insufficient, then

determining whether the additional provider digital content data is preferred to the provider digital content data: and

if it determined that the additional provider digital content data is preferred, then determining that conditions are satisfied for deleting the provider data from the non-volatile storage.

42. An apparatus as recited in Claim 31, wherein:

execution of the one or more sequences of instructions further causes the one or more processors to perform the step of receiving, from a content managing server of the network service provider, policy data that indicates how to determine provider digital content data: and

said step of receiving provider digital content data further comprising receiving provider digital content data based on the policy data
An apparatus as recited in Claim 31, wherein

evolution of the one or more sequences of instructions funhei causes the one or
more processors to perform the step of receding, from a content managing
server of the network service. A data that indicates the
conditions to be satisfied for sending the provider digital content data to
another customer, and

said step of determining whether conditions are satisfied for sending the provider
digital content data to the second customer is based on the provider data

An apparatus as recited in Claim 31, wherein

evolution of the one or more sequences of instructions fuiihei causes the one or
more processors to perform the step of receding, from a content managing
server of the network service. A data that indicates the
conditions to be satisfied for deleting the provider data from the non-
volatile storage, and

said step of determining whether conditions are satisfied for deleting the provider
data from the nonvolatile storage is based on the provider data

An apparatus as recited in Claim 31, said step of sending data based on the
provider data o\'ei the network interface for receipt by the second customer in either
composing, sending the data based on the provider content using a particular channel for
communication among customer premises nodes, wherein the particular channel is not
used for receiving provider content from the network service provider.

An apparatus as recited in Claim 31, said step of sending data based on the
provider data n\'er the network interface for receipt by the second customer further
computing decision provider data

An apparatus as recited in Claim 31, said step of storing the provider data based on
the provider digital content data further comprising storing compressed provider digital
content data
An apparatus sensing as a prcn ider node on a network of a network sen ice

pro\der fof distributing digital content at a customer pjeiuses node located on pr\mises

of a first customer comprising

a net\wk interface that is coupled to a packet switched nem oik for

communicating therewith a data packet.

one or more sequences of instructions stored in the computer-readable medium, and

which, when executed by the one or moie processors, causes the one or

moio procesbsors to earn via the step of

reec ing cu\ntomer data that indicates a cu\ntomer set of one or more

customers each customer different from the network i-s-p ice

pro\der wherein the network sen ice pr\der p\\ ides access to

the network for the customer set, and

icen mg host data that indicates a host set of one or moie customer

premises nodes on premises of a customer subset of the customer

set wherein the host set is available for redistributing pro\der

content data offered by the network sen ice pr\\ ider,

causing a conten er on a first customiei premises node of the host set

to perform the steps of

caching pro\ ider content data offered by the network sen ice.

delei

whether conditions are satisfied for sending the

pro\ ider content data to a particular customer of the

customer set, and

if it is determined that conditions are satisfied for sending the

pro\ ider content data, then sending the pr\ ider content

data to the particular customer

An apparatus as rooted to claim 48, said step of causing the content set\er on the

first customer premises node to perform the step of caching pro\ ider content data further

composing the step of installing the content set er on the fast customer premises node
50. An apparatus as recited in claim 48, wherein:
   execution of the one or more sequences of instructions further causes the one or
   more processors to perform the step of receiving policy data that indicates
   conditions for caching provider content data on customer premises node
   for the customer subset; and
   said step of causing the content server on the first customer premises node to
   perform the step of caching provider content data further comprising
   sending the policy data to the first customer premises node.

51. An apparatus as recited in claim 48, wherein:
   execution of the one or more sequences of instructions further causes the one or
   more processors to perform the step of receiving policy data that indicates
   conditions for sending the provider content data to a particular customer of
   the customer set; and
   said step of causing the content server on the first customer premises node to
   perform the step of determining conditions for sending the provider
   content data to a particular customer further comprising sending the policy
   data to the first customer premises node.

52. An apparatus as recited in claim 48, said caching provider content data on
   customer premises node further comprising at least one of:
   storing the provider content data for archival under control of the provider node;
   storing the provider content data seeded from the provider node under control of
   the content server; and
   storing the provider content received from second customer premises node on
   premises of a different second customer of the customer subset.
53. An apparatus as recited in claim 48, wherein execution of the one or more
sequences of instructions further causes the one or more processors to perform the steps
doing:

determining whether conditions are satisfied for archiving provider content on the
first customer premises node; and

if it is determined that conditions are satisfied for archiving provider content on
the first customer premises node, then causing the provider content and an
associated archival flag data to be sent to the content server, wherein the
archival flag data indicates that the associated provider content is to be
stored for archival under control of the provider node.

54. An apparatus as recited in claim 48, wherein execution of the one or more
sequences of instructions further causes the one or more processors to perform the steps
doing:

determining whether conditions are satisfied for seeding provider content on the
first customer premises node: and

if it is determined that conditions are satisfied for seeding provider content on the
first customer premises node, then causing the provider content and
associated release conditions data to be sent to the content server, wherein the
release conditions data indicates how the associated provider content is
to be distributed to the particular customer.

55. An apparatus as recited in claim 48, wherein execution of the one or more
sequences of instructions further causes the one or more processors to perform the steps
doing:

determining whether conditions are satisfied for responding, at the content server,
to a request for the provider content from the particular customer; and

if it is determined that conditions are satisfied for responding, at the content
server, to a request for the provider content from the particular customer,
then causing the request to be sent to the content server.
5(6) An apparatus as recited in claim 48, said step of receiving host data further comprising
causing a mechanism to be offered to the customer set to make customer premises
node available. "Cot" distributing provided content data, and
recieving the host data in response to causing the mechanism to be offered
FIG. 2

200 METHOD AT CUSTOMER PREMISES EQUIPMENT

202
RECEIVE PROVIDER CONTENT POLICY DATA

210
RECEIVE PROVIDER CONTENT DATA

220
CONDITIONS SATISFIED FOR STORING?

YES

222
CONVENTIONAL PROCESSING

NO

230
CONDITIONS SATISFIED FOR DELETING PRIOR DATA?

YES

232
DELETE PREVIOUSLY STORED PROVIDER CONTENT DATA

NO

240
STORE PROVIDER CONTENT DATA ON LOCAL NON-VOLATILE STORAGE

250
CONDITIONS SATISFIED FOR SENDING?

YES

260
RETRIEVE AND SEND PROVIDER CONTENT DATA FROM LOCAL NON-VOLATILE STORAGE

NO
FIG. 3

300 METHOD AT CONTENT MANAGER

302 RECEIVE PROVIDER CONTENT POLICY DATA

310 RECEIVE DATA INDICATING CUSTOMER PREMISES NODES (CPN) TO HOST CONTENT SERVERS

320 INSTALL CONTENT SERVERS ON THOSE CPN

322 SEND PROVIDER CONTENT POLICY DATA TO CONTENT SERVERS

330 CONDITIONS SATISFIED FOR ARCHIVING CONTENT TO CPN?

332 SEND CONTENT AND ARCHIVAL FLAG TO CONTENT SERVERS ON CPN

340 CONDITIONS SATISFIED FOR SEEDING CONTENT TO CPN?

342 SEND CONTENT AND RELEASE CONDITIONS TO CONTENT SERVERS ON CPN

350 CONDITIONS SATISFIED FOR Responding TO REQUEST AT CPN?

352 SEND REQUEST INFO TO CONTENT SERVER ON CPN

354 CAUSE CONTENT TO BE SENT REQUESTER AND CONTENT SERVER ON CPN