US008296812B1

(12) **United States Patent**
Ganesan

(10) **Patent No.: US 8,296,812 B1**
(45) **Date of Patent: Oct. 23, 2012**

(54) **STREAMING VIDEO USING ERASURE ENCODING**

(75) Inventor: **Prasanna Ganesan**, Menlo Park, CA (US)

(73) Assignee: **Vudu, Inc.**, Santa Clara, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 388 days.

(21) Appl. No.: **11/515,267**

(22) Filed: **Sep. 1, 2006**

(51) **Int. Cl.**
H04N 7/173 (2011.01)

(52) **U.S. Cl.** **725/95**; 725/8; 725/87; 725/88; 725/90; 725/97; 725/101

(58) **Field of Classification Search** 725/86, 725/87, 88, 90, 95, 97, 101
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,132,992	A		7/1992	Yurt et al.
5,414,455	A		5/1995	Hooper et al.
5,602,918	A		2/1997	Chen et al.
RE35,651	E		11/1997	Bradley et al.
5,694,559	A		12/1997	Hobson et al.
5,701,582	A		12/1997	DeBey
5,721,878	A	*	2/1998	Ottesen et al. 725/87
5,729,280	A		3/1998	Inoue et al.
5,761,417	A	*	6/1998	Henley et al. 709/231
5,765,164	A		6/1998	Prasad et al.
5,802,283	A		9/1998	Grady et al.
5,815,146	A		9/1998	Youden et al.
5,815,662	A		9/1998	Ong
5,826,168	A		10/1998	Inoue et al.
5,831,662	A		11/1998	Payton
5,838,314	A		11/1998	Neel et al.
5,877,812	A		3/1999	Krause et al.
5,884,031	A		3/1999	Ice
5,903,563	A		5/1999	Rashid et al.

(Continued)

FOREIGN PATENT DOCUMENTS

WO	WO 97/016023	5/1997

(Continued)

OTHER PUBLICATIONS

U.S. Appl. No. 11/150,653, filed Jun. 11, 2005, Ganesan et al.

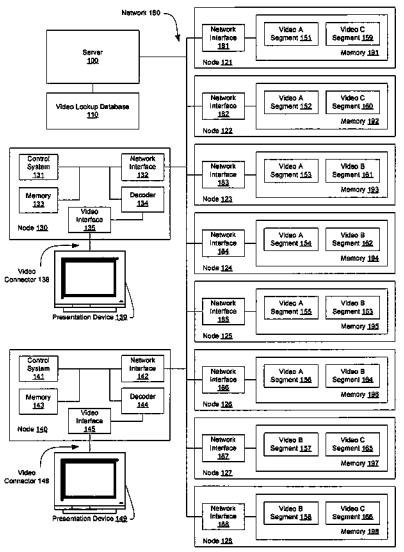
(Continued)

Primary Examiner — Pankaj Kumar
Assistant Examiner — Sahar Baig
(74) *Attorney, Agent, or Firm* — Stevens Law Group; David R. Stevens

(57) **ABSTRACT**

A system, apparatus and method for presenting a movie on demand over a network is described. According to one system and method, the network has one or more nodes, portions of a video being encoded as encoded portions each having sections, the sections for each encoded portion being distributed among segments, the segments being distributed among the one or more nodes; an apparatus including a network interface is coupled to the network; a control system is coupled to the network interface and configured to initiate a movie request and to communicate with a subset of the one or more nodes to receive a subset of the segments; and a decoder coupled to the network interface and configured to decode a subset of the sections so that less than all of the sections are used to play back the movie; and a presentation device coupled to the apparatus, the presentation device presenting the portions of the video. Each portion of the movie is played back, in its entirety, without using all of the sections of that portion.

18 Claims, 8 Drawing Sheets



U.S. PATENT DOCUMENTS

5,926,205	A	7/1999	Krause et al.	
5,928,331	A	7/1999	Bushmitch	
5,933,603	A	8/1999	Vahalia et al.	
5,948,070	A	9/1999	Fujita	
6,018,359	A	1/2000	Kermode et al.	
6,037,983	A	3/2000	Au et al.	
6,038,560	A	3/2000	Wical	
6,055,314	A	4/2000	Spies et al.	
6,124,854	A *	9/2000	Sartain et al.	715/716
6,138,221	A	10/2000	Korst et al.	
6,170,006	B1	1/2001	Namba	
6,184,878	B1	2/2001	Alonso et al.	
6,212,549	B1	4/2001	Page et al.	
6,236,504	B1	5/2001	Kao et al.	
6,263,504	B1	7/2001	Ebisawa	
6,324,519	B1	11/2001	Eldering	
6,334,124	B1	12/2001	Bouchard et al.	
6,397,251	B1	5/2002	Graf	
6,463,508	B1	10/2002	Wolf et al.	
6,502,139	B1 *	12/2002	Birk et al.	709/233
6,519,693	B1 *	2/2003	Debey	712/201
6,614,366	B2	9/2003	Luby	
6,622,305	B1	9/2003	Willard	
6,630,963	B1	10/2003	Billmaier	
6,640,241	B1	10/2003	Ozzie et al.	
6,701,528	B1	3/2004	Arsenault et al.	
6,704,813	B2	3/2004	Smirnov et al.	
6,728,763	B1	4/2004	Chen	
6,731,605	B1	5/2004	Deshpande	
6,763,392	B1	7/2004	del Val et al.	
6,789,106	B2	9/2004	Eyer et al.	
6,801,947	B1	10/2004	Li	
6,804,719	B1	10/2004	Cabrera et al.	
6,857,012	B2	2/2005	Sim et al.	
6,934,965	B2	8/2005	Gordon et al.	
6,938,258	B1	8/2005	Weinberger et al.	
6,944,585	B1	9/2005	Pawson	
6,970,937	B1	11/2005	Huntington	
6,973,667	B2	12/2005	Fritsch	
7,051,360	B1	5/2006	Ellis et al.	
7,080,400	B1 *	7/2006	Navar	725/139
7,110,006	B2	9/2006	MacInnis et al.	
7,155,735	B1 *	12/2006	Ngo et al.	725/101
7,174,385	B2	2/2007	Li	
7,188,357	B1 *	3/2007	Rieschl et al.	725/92
7,191,215	B2	3/2007	Ganesan et al.	
7,228,556	B2	6/2007	Beach et al.	
7,240,359	B1	7/2007	Sie et al.	
7,246,369	B1	7/2007	Duan et al.	
7,260,829	B1	8/2007	Hendricks et al.	
7,324,555	B1	1/2008	Chen et al.	
7,360,235	B2	4/2008	Davies et al.	
7,379,963	B1	5/2008	Khare et al.	
7,386,874	B2	6/2008	White et al.	
7,552,382	B1 *	6/2009	Munetsugu et al.	715/204
7,577,750	B2	8/2009	Shen et al.	
7,633,887	B2	12/2009	Panwar et al.	
7,810,647	B2	10/2010	Ganesan et al.	
2001/0019630	A1	9/2001	Johnson	
2001/0042249	A1	11/2001	Knepper et al.	
2001/0051998	A1 *	12/2001	Henderson	709/217
2002/0012521	A1 *	1/2002	Nagasaka et al.	386/46
2002/0022956	A1	2/2002	Ukrainczyk	
2002/0029282	A1	3/2002	Buddhikot et al.	
2002/0031331	A1	3/2002	Kwoh et al.	
2002/0053078	A1	5/2002	Holtz et al.	
2002/0091825	A1 *	7/2002	Shuster	709/226
2002/0129375	A1	9/2002	Kim et al.	
2002/0131423	A1	9/2002	Chan et al.	
2002/0133491	A1	9/2002	Sim et al.	
2002/0143959	A1	10/2002	El-Baze et al.	
2002/0154703	A1 *	10/2002	Kubota et al.	375/260
2002/0154892	A1	10/2002	Hoshen et al.	
2002/0162109	A1	10/2002	Shteyn	
2002/0163882	A1	11/2002	Bornstein et al.	
2003/0026254	A1	2/2003	Sim	
2003/0028490	A1	2/2003	Miura et al.	
2003/0055893	A1	3/2003	Sato et al.	
2003/0078964	A1	4/2003	Parrella et al.	
2003/0084461	A1	5/2003	Hoang	
2003/0097661	A1 *	5/2003	Li et al.	725/109
2003/0126277	A1	7/2003	Son et al.	
2003/0135867	A1	7/2003	Guedalia	
2003/0163646	A1	8/2003	O'Neil	
2003/0188316	A1	10/2003	DePrez	
2003/0188317	A1	10/2003	Liew et al.	
2003/0204613	A1	10/2003	Hudson et al.	
2003/0204856	A1 *	10/2003	Buxton	725/120
2003/0208612	A1	11/2003	Harris et al.	
2004/0016000	A1	1/2004	Zhang et al.	
2004/0078460	A1	4/2004	Valavi et al.	
2004/0107242	A1	6/2004	Vert et al.	
2004/0123324	A1	6/2004	Sazzad et al.	
2004/0128343	A1	7/2004	Mayer	
2004/0133923	A1	7/2004	Watson et al.	
2004/0143672	A1	7/2004	Padmanabham et al.	
2004/0143850	A1 *	7/2004	Costa	725/115
2004/0148634	A1	7/2004	Arsenault et al.	
2004/0148636	A1	7/2004	Weinstein et al.	
2004/0158867	A1 *	8/2004	Mack et al.	725/95
2004/0202073	A1	10/2004	Lai et al.	
2004/0236869	A1	11/2004	Moon	
2004/0250286	A1	12/2004	Fraser et al.	
2004/0255323	A1	12/2004	Varadarajan et al.	
2004/0267822	A1	12/2004	Curran et al.	
2005/0010653	A1	1/2005	McCanne	
2005/0015511	A1 *	1/2005	Izmailov et al.	709/238
2005/0033856	A1	2/2005	Li	
2005/0038724	A1	2/2005	Roever et al.	
2005/0041679	A1	2/2005	Weinstein et al.	
2005/0055425	A1	3/2005	Lango et al.	
2005/0055718	A1	3/2005	Stone	
2005/0066063	A1	3/2005	Grigorovitch et al.	
2005/0086696	A1	4/2005	Daniels	
2005/0097213	A1	5/2005	Barrett et al.	
2005/0108414	A1	5/2005	Taylor et al.	
2005/0177853	A1	8/2005	Williams et al.	
2005/0216941	A1	9/2005	Flanagan et al.	
2005/0259682	A1 *	11/2005	Yosef et al.	370/468
2005/0267948	A1 *	12/2005	McKinley et al.	709/217
2006/0008256	A1	1/2006	Khedouri et al.	
2006/0026663	A1	2/2006	Kortum et al.	
2006/0031537	A1	2/2006	Boutboul et al.	
2006/0034537	A1	2/2006	Masaki	
2006/0037037	A1	2/2006	Miranz	
2006/0075453	A1	4/2006	Choi	
2006/0095948	A1	5/2006	Verhaegh et al.	
2006/0106807	A1	5/2006	DeVitis et al.	
2006/0136597	A1	6/2006	Shabtai et al.	
2006/0174160	A1	8/2006	Kim	
2006/0184688	A1	8/2006	Ganguly et al.	
2006/0190615	A1	8/2006	Panwar et al.	
2006/0190975	A1	8/2006	Gonzalez	
2006/0206889	A1	9/2006	Ganesan et al.	
2006/0218217	A1	9/2006	Ganesan et al.	
2006/0242153	A1	10/2006	Newberry et al.	
2007/0089146	A1	4/2007	Ikeda et al.	
2007/0143804	A1 *	6/2007	Wang	725/95
2008/0022343	A1	1/2008	Hodzic et al.	
2008/0091840	A1	4/2008	Guo et al.	
2008/0134258	A1 *	6/2008	Goose et al.	725/91
2008/0148323	A1	6/2008	White et al.	
2008/0212945	A1	9/2008	Khedouri et al.	
2008/0256272	A1	10/2008	Kampmann et al.	
2008/0281913	A1	11/2008	Shankar et al.	
2008/0282036	A1	11/2008	Ganesan	
2008/0282298	A1	11/2008	Ganesan et al.	
2008/0301738	A1	12/2008	Davies et al.	
2009/0007196	A1	1/2009	Ganesan	
2009/0019174	A1	1/2009	Ehn et al.	
2009/0019468	A1	1/2009	Ganesan et al.	
2009/0024573	A1	1/2009	Zink	
2009/0025046	A1	1/2009	Ganesan et al.	
2009/0025048	A1	1/2009	Ganesan	
2010/0049867	A1	2/2010	Panwar et al.	
2010/0223362	A1	9/2010	Price	
2010/0254675	A1	10/2010	Ganesan	

2011/0023072	A1	1/2011	Hodzic et al.
2011/0093492	A1	4/2011	Sull et al.
2011/0179449	A1	7/2011	Ganesan et al.

FOREIGN PATENT DOCUMENTS

WO	WO 01/024526	4/2001
WO	WO 03/041383	5/2003

OTHER PUBLICATIONS

U.S. Appl. No. 11/404,972, filed Apr. 13, 2006, Ganesan.
U.S. Appl. No. 11/927,690, filed Oct. 30, 2007, Ganesan et al.
Video-on-Demand Research, printable at http:llwww.cs. ndsu. nodak.edu/-rvetterlATM/html/video. html.
C. Siva Ram Murthy "A Primary-Segmented Backup Scheme for Fast Restoration of Real-Time Channels from Network Component Failures", printable at http://www.prl.ernet.in/-library/Hari200m/Hari%200 m%20Lecture/Siva%20Ram%20Murthy final.html.
Clifford A. Shaffer, A Practical Introduction to Data Structures and Algorithm Analysis Java Edition, 1998, 11 pgs.
Decision on Petition to Make Special dated Apr. 16, 2005 in U.S. Appl. No. 11/077,411, 1 pg.
Decision on Petition to Make Special dated Dec. 18, 2007 in U.S. Appl. No. 11/974,138, 2 pgs.
Decision on Petition to Make Special dated Nov. 29, 2005 in U.S. Appl. No. 11/075,573, 1 pg.
Final Office Action dated Dec. 29, 2008 in U.S. Appl. No. 11/210,272, 19 pgs.
Final Office Action dated Apr. 24, 2006 in U.S. Appl. No. 11/077,411, 7 pgs.
Final Office Action dated Dec. 3, 2008 in U.S. Appl. No. 11/458,384, 24 pgs.
Final Office Action dated Aug. 31, 2009 in U.S. Appl. No. 11/492,673, 16 pgs.
Final Office Action dated Mar. 18, 2008 in U.S. Appl. No. 11/075,573, 18 pgs.
Final Office Action dated Aug. 31, 2009 in U.S. Appl. No. 11/278,416, 15 pgs.
Final Office Action dated Aug. 14, 2009 in U.S. Appl. No. 11/150,653, 27 pgs.
Francois, Alexandre R.J., "A Hybrid Architectural Style for Distributed Parallel Processing of Generic Data Streams" May 2004, IEEE Computer Society, ICSE '04: Proceedings of the 26th International Conference on Software Engineering, pp. 1-10.
Guo, Yang et al., "P2Cast: Peer-to-peer Patching Scheme for VoD Service" May 2003, ACM, WWW '03: Proceedings of the 12th international conference on World Wide Web, pp. 301-309.
International Preliminary Report on Patentability and Written Opinion in the International Application PCT/US2005/020051, World Intellectual Property Organization, European Patent Office, Apr. 3, 2007, 4 pages.
International Preliminary Report on Patentability and Searching Authority in the International Application PCT/US2006/007070, World IntellectualProperty Organization, European Patent Office, Sep. 12,2007,7 pages, Written Opinion of the International.
International Search Report and Written Opinion of the International Searching Authority inInternational Application PCT/US2006/007070, European Patent Office, Feb. 27,2006, 12 pages.
International Search Report and Written Opinion of the International Searching Authority inInternational Application PCT/US2008/071735, European Patent Office, Feb. 19, 2009, 11 pages.
International Search Report International Searching Authority inInternational Application PCT/US2005/020051, European Patent Office, Mar. 9, 2007, 3 pages.
International Search Report and Written Opinion of the International Searching Authority inInternational Application PCT/US2006/007070, European Patent Office, Apr. 19, 2007, 9 pages.
Jim Ferrara, Creating and Maintaining a Hierarchical Directory, Nov. 2002, 14 pgs.
Lisa Payne, Web Authoring Inline Images, Jan. 2002, 4 pgs.
Non-Final Office Action dated Mar. 11, 2009 in U.S. Appl. No. 11/492,673, 12 pgs.
Non-Final Office Action dated Dec. 26, 2008 in U.S. Appl. No. 11/150,653, 26 pgs.
Non-Final Office Action dated Sep. 23, 2008 in U.S. Appl. No. 11/684,637, 5 pgs.
Non-Final Office Action dated Jul. 20, 2009 in U.S. Appl. No. 11/930,147, 14 pgs.
Non-Final Office Action dated Jul. 2, 2009 in U.S. Appl. No. 11/331,113, 10 pgs.
Non-Final Office Action dated Oct. 28, 2008 in U.S. Appl. No. 10/867,155, 12 pgs.
Non-Final Office Action dated May 13, 2009 in U.S. Appl. No. 11/685,101, 10 pgs.
Non-Final Office Action dated Jan. 30, 2006 in U.S. Appl. No. 11/077,411, 6 pgs.
Non-Final Office Action dated Aug. 28, 2006 in U.S. Appl. No. 11/077,411, 10 pgs.
Non-Final Office Action dated Jun. 30, 2008 in U.S. Appl. No. 11/075,573, 19 pgs.
Non-Final Office Action dated Jun. 20, 2008 in U.S. Appl. No. 11/210,272, 16 pgs.
Non-Final Office Action dated Apr. 29, 2008 in U.S. Appl. No. 11/458,384, 24 pgs.
Non-Final Office Action dated Mar. 13, 2009 in U.S. Appl. No. 11/278,416, 9 pgs.
Non-Final Office Action dated Jun. 11, 2009 in U.S. Appl. No. 11/210,272, 23 pgs.
Non-Final Office Action dated Nov. 25, 2008 in U.S. Appl. No. 11/075,573, 18 pgs.
Non-Final Office Action dated Oct. 17, 2007 in U.S. Appl. No. 11/075,573, 13 pgs.
Notice of Allowance dated Aug. 27, 2009 in U.S. Appl. No. 11/684,637, 3 pgs.
Notice of Allowance dated Jan. 16, 2007 in U.S. Appl. No. 11/077,411, 4 pgs.
Paris et al.: "Zero-delay broadcasting protocols for video-on-demand", ACM Multimedia, Proceedings of the International Conference, New York, NY, US, Oct. 30, 1999, 9 pages.
Petition to Make Special dated Mar. 9, 2005 in U.S. Appl. No. 11/077,411, 52 pgs.
Petition to Make Special dated Oct. 10, 2007 in U.S. Appl. No. 11/974,138, 9 pgs.
Petition to Make Special dated Oct. 31, 2005 in U.S. Appl. No. 11/075,573, 16 pgs.
Video-on-Demand Research, from http://www.cs.ndsu.nodak.edu/-rvetterlATM/html/video.html, dated Oct. 31, 2005, North Dakota State University, Computer Science Department, 2 pgs.
C. Siva Ram Murthy "A Primary-Segmented Backup Scheme for Fast Restoration of Real-Time Channels from Network Component Failures", from http://www.prl.ernet.in/-library/Hari%200m/Hari%200m%20Lecture/Siva%/20Ram%20Murthy final.html, dated Oct. 31, 2005, Indian Institute of Technology, Department ofComputer Science and Engineering, 8 pgs.
Election/Restriction Requirement dated Oct. 28, 2009 in U.S. Appl. No. 11/404,972, 6 pgs.
Final Office Action date Jan. 21, 2010 in U.S. Appl. No. 11/075,573,24pages.
Final Office Action dated Sep. 30, 2009 in U.S. Appl. No. 11/269,462, 27 pgs.
Final Office Action date Aug. 4, 2009 in U.S. Appl. No. 11/076,214, 16 pages.
Final Office Action date May 5, 2010 in U.S. Appl. No. 11/269,462, 10 pages.
Final Office Action Mar. 18, 2010 in U.S. Appl. No. 11/331,113 15pages.
Final Office Action date Mar. 26, 2010 in U.S. Appl. No. 11/930,147, 13 pages.
International Preliminary Report on Patentability and Written Opinion of the International Searching Authority in International Application PCT/US2008/071735, European Patent Office, Feb. 11, 2010, 7 pages.
Non-Final Office Actipn Mar. 12, 2010 in U.S. Appl. No. 11/150,653 29pages.

Non-Final Office Action date Mar. 4, 2010 in U.S. Appl. No. 11/076,214, 13 pages.
Non-Final Office Action dated Dec. 16, 2009 in U.S. Appl. No. 11/684,637, 5 pgs.
Non-Final Office Action dated Dec. 1, 2009 in U.S. Appl. No. 11/831,938, 16 pgs.
Non-Final Office Action date Mar. 24, 2010 in U.S. Appl. No. 11/404,972, 10 pages.
Non-Final Office Action date Apr. 12, 2010 in U.S. Appl. No. 11/492,673, 11 pages.
Non-Final Office Action date Dec. 23, 2008 in U.S. Appl. No. 11/076,214,19pages.
Notice of Allowance dated Nov. 2, 2009 in U.S. Appl. No. 11/685,101, 6 pgs.
Final Office Action dated Oct. 14, 2010 in U.S. Appl. No. 11/076,214, 12 pages.
Final Office Action dated Sep. 28, 2010 in U.S. Appl. No. 11/492,673, 12 pages.
Final Office Action dated Sep. 17, 2010 in U.S. Appl. No. 11/150,653; 31 pages.
Final Office Action date Aug. 31, 2010 in U.S. Appl. No. 11/831,938; 29 pages.
Notice of Allowance dated Jun. 10, 2010 in U.S. Appl. No. 11/684,637; 8 pages.
U.S. Appl. No. 60/646,080 Specification, Panwar, Jan. 2005.
Communication of Dec. 16, 2010 in European Application No. 08796939.0-1244.
Final Office Action dated Aug. 30, 2011 in U.S. Appl. No. 11/492,673.
Final Office Action dated Jul. 22, 2011 in U.S. Appl. No. 11/075,573.
Ma et al., "Reducing bandwidth requirement for delivering video over wide area networks with proxy server", IEEE, 2002, vol. 4, Iss. 4, p. 539-550.
Non-Final Office Action dated Jul. 8, 2011 in U.S. Appl. No. 11/831,938.
Non-Final Office Action dated Apr. 21, 2011 in U.S. Appl. No. 11/278,416.
Non-Final Office Action dated Mar. 14, 2011 in U.S. Appl. No. 11/492,673, 15 pages.
Non-Final Office Action dated Mar. 14, 2011 in U.S. Appl. No. 11/150,653.
Non-Final Office Action dated Feb. 25, 2011 in U.S. Appl. No. 11,075,573, 27 pages.
Notice of Allowance mailed Sep. 13, 2011 in U.S. Appl. No. 11/150,653.
Ramesh et al., "Multicast with cache (Mcache): an adaptive zero-delay video-on-demand service", IEEE, 2001. vol. 11, Iss. 3; p. 440-456.

* cited by examiner

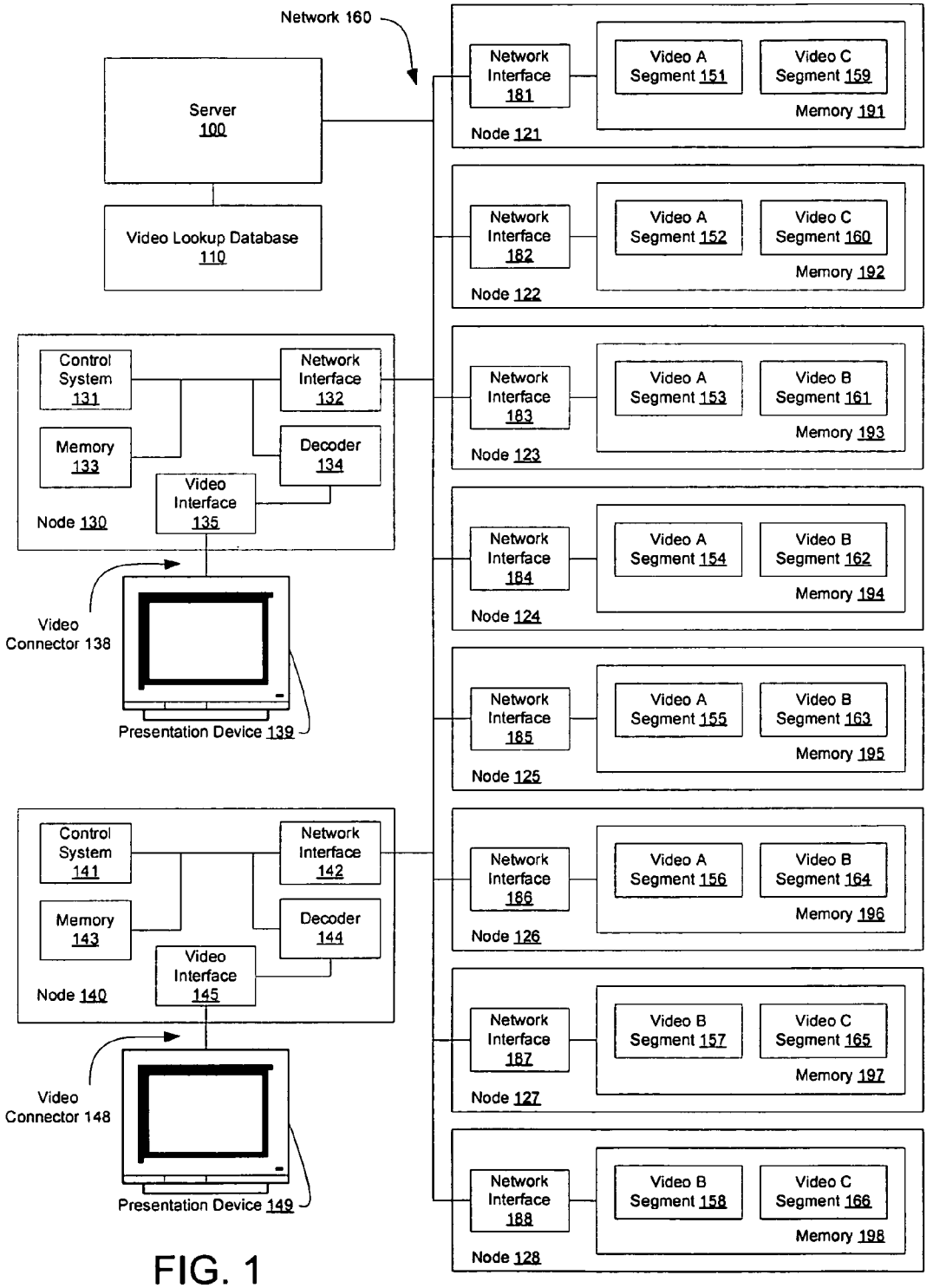

Network 160
Server 100
Video Lookup Database 110
Control System 131
Network Interface 132
Memory 133
Decoder 134
Video Interface 135
Node 130
Video Connector 138
Presentation Device 139
Control System 141
Network Interface 142
Memory 143
Decoder 144
Video Interface 145
Node 140
Video Connector 148
Presentation Device 149
Network Interface 181
Video A Segment 151
Video C Segment 159
Memory 191
Node 121
Network Interface 182
Video A Segment 152
Video C Segment 160
Memory 192
Node 122
Network Interface 183
Video A Segment 153
Video B Segment 161
Memory 193
Node 123
Network Interface 184
Video A Segment 154
Video B Segment 162
Memory 194
Node 124
Network Interface 185
Video A Segment 155
Video B Segment 163
Memory 195
Node 125
Network Interface 186
Video A Segment 156
Video B Segment 164
Memory 196
Node 126
Network Interface 187
Video B Segment 157
Video C Segment 165
Memory 197
Node 127
Network Interface 188
Video B Segment 158
Video C Segment 166
Memory 198
Node 128

FIG. 1

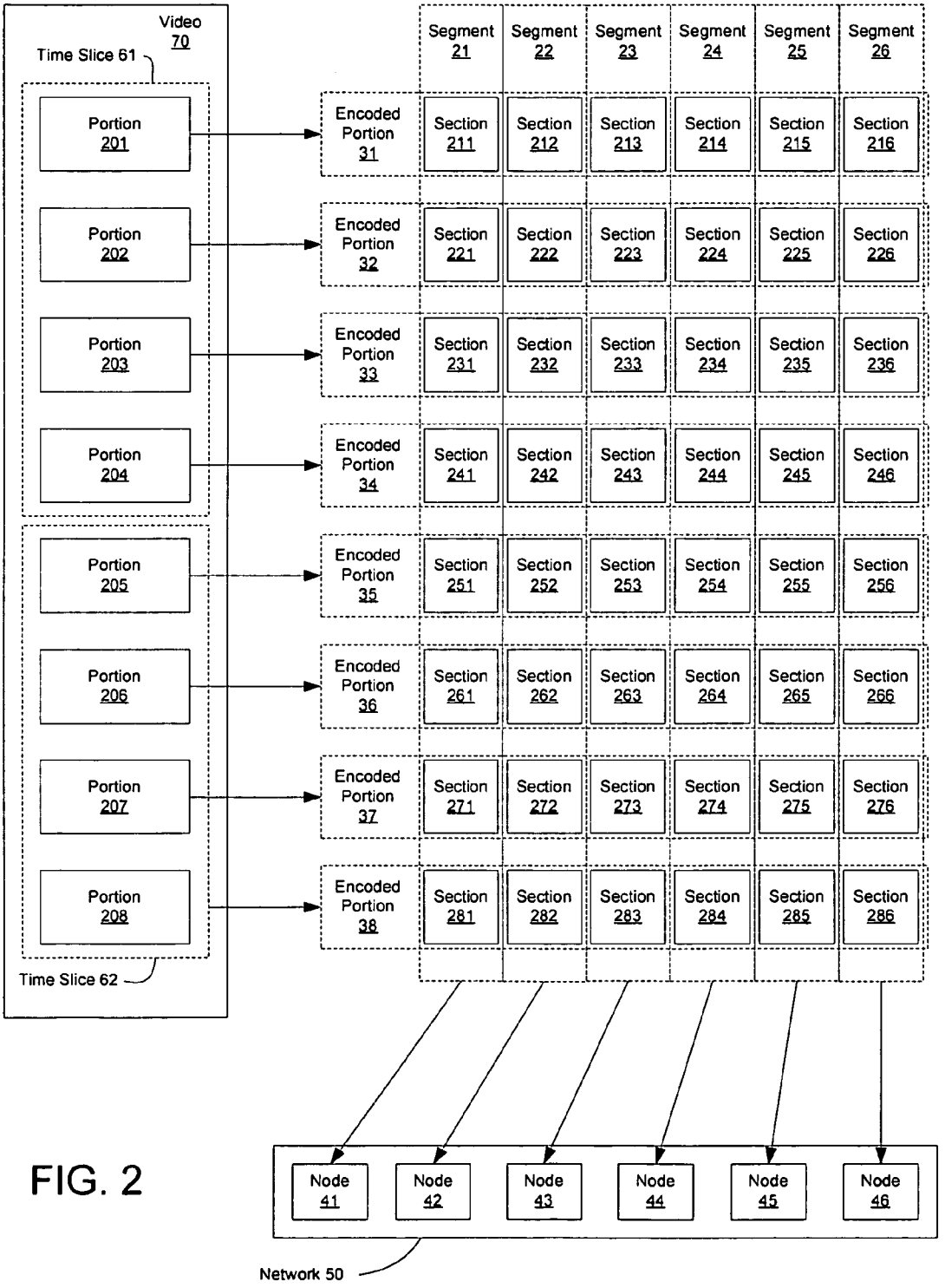

Video 70
Time Slice 61
Time Slice 62
Portion 201
Portion 202
Portion 203
Portion 204
Portion 205
Portion 206
Portion 207
Portion 208
Segment 21
Segment 22
Segment 23
Segment 24
Segment 25
Segment 26
Encoded Portion 31
Encoded Portion 32
Encoded Portion 33
Encoded Portion 34
Encoded Portion 35
Encoded Portion 36
Encoded Portion 37
Encoded Portion 38
Section 211
Section 212
Section 213
Section 214
Section 215
Section 216
Section 221
Section 222
Section 223
Section 224
Section 225
Section 226
Section 231
Section 232
Section 233
Section 234
Section 235
Section 236
Section 241
Section 242
Section 243
Section 244
Section 245
Section 246
Section 251
Section 252
Section 253
Section 254
Section 255
Section 256
Section 261
Section 262
Section 263
Section 264
Section 265
Section 266
Section 271
Section 272
Section 273
Section 274
Section 275
Section 276
Section 281
Section 282
Section 283
Section 284
Section 285
Section 286
Node 41
Node 42
Node 43
Node 44
Node 45
Node 46
Network 50

FIG. 2

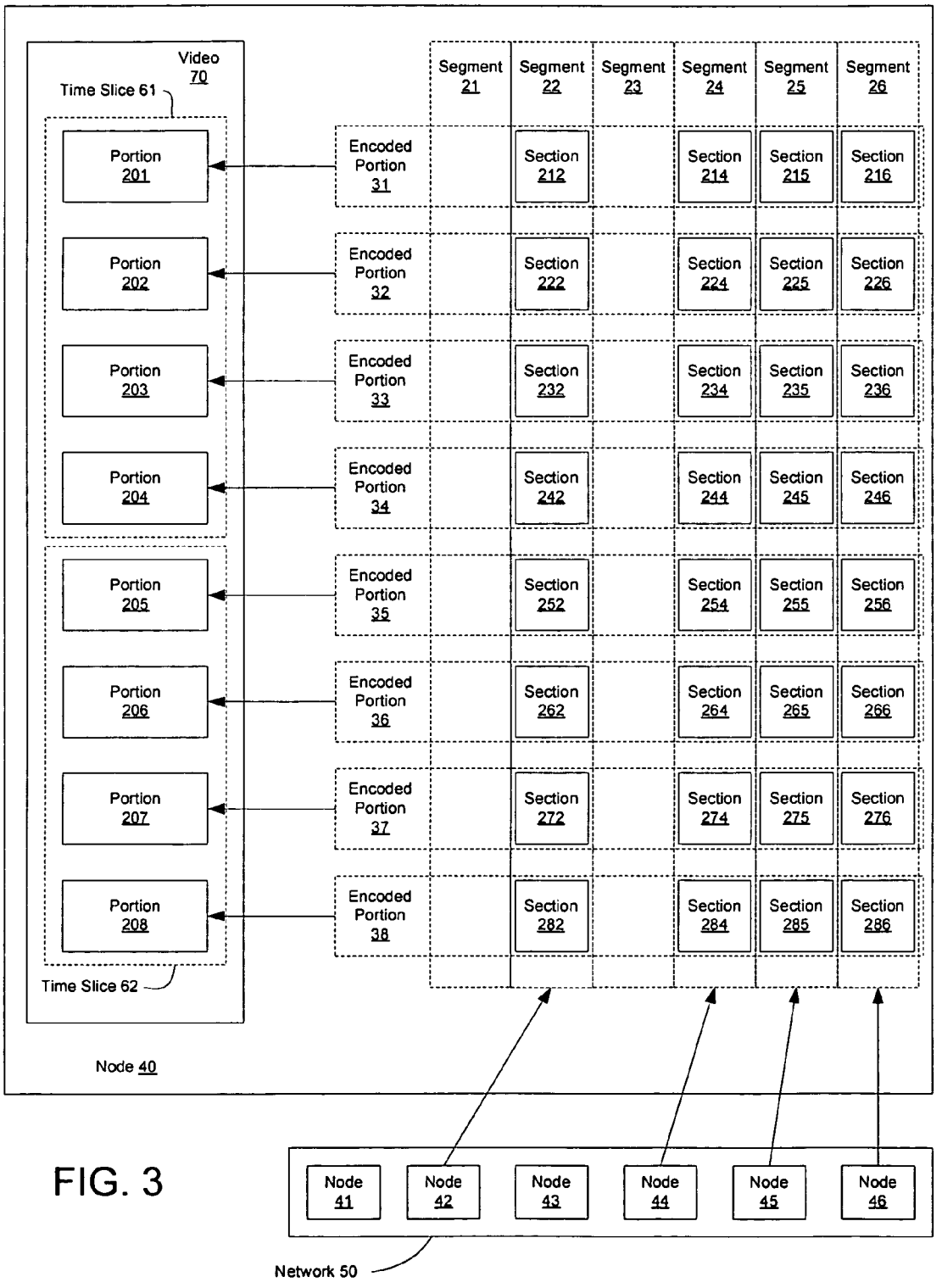

Video 70
Time Slice 61
Segment 21
Segment 22
Segment 23
Segment 24
Segment 25
Segment 26
Portion 201
Encoded Portion 31
Section 212
Section 214
Section 215
Section 216
Portion 202
Encoded Portion 32
Section 222
Section 224
Section 225
Section 226
Portion 203
Encoded Portion 33
Section 232
Section 234
Section 235
Section 236
Portion 204
Encoded Portion 34
Section 242
Section 244
Section 245
Section 246
Portion 205
Encoded Portion 35
Section 252
Section 254
Section 255
Section 256
Portion 206
Encoded Portion 36
Section 262
Section 264
Section 265
Section 266
Portion 207
Encoded Portion 37
Section 272
Section 274
Section 275
Section 276
Portion 208
Encoded Portion 38
Section 282
Section 284
Section 285
Section 286
Time Slice 62
Node 40
Node 41
Node 42
Node 43
Node 44
Node 45
Node 46
Network 50

FIG. 3

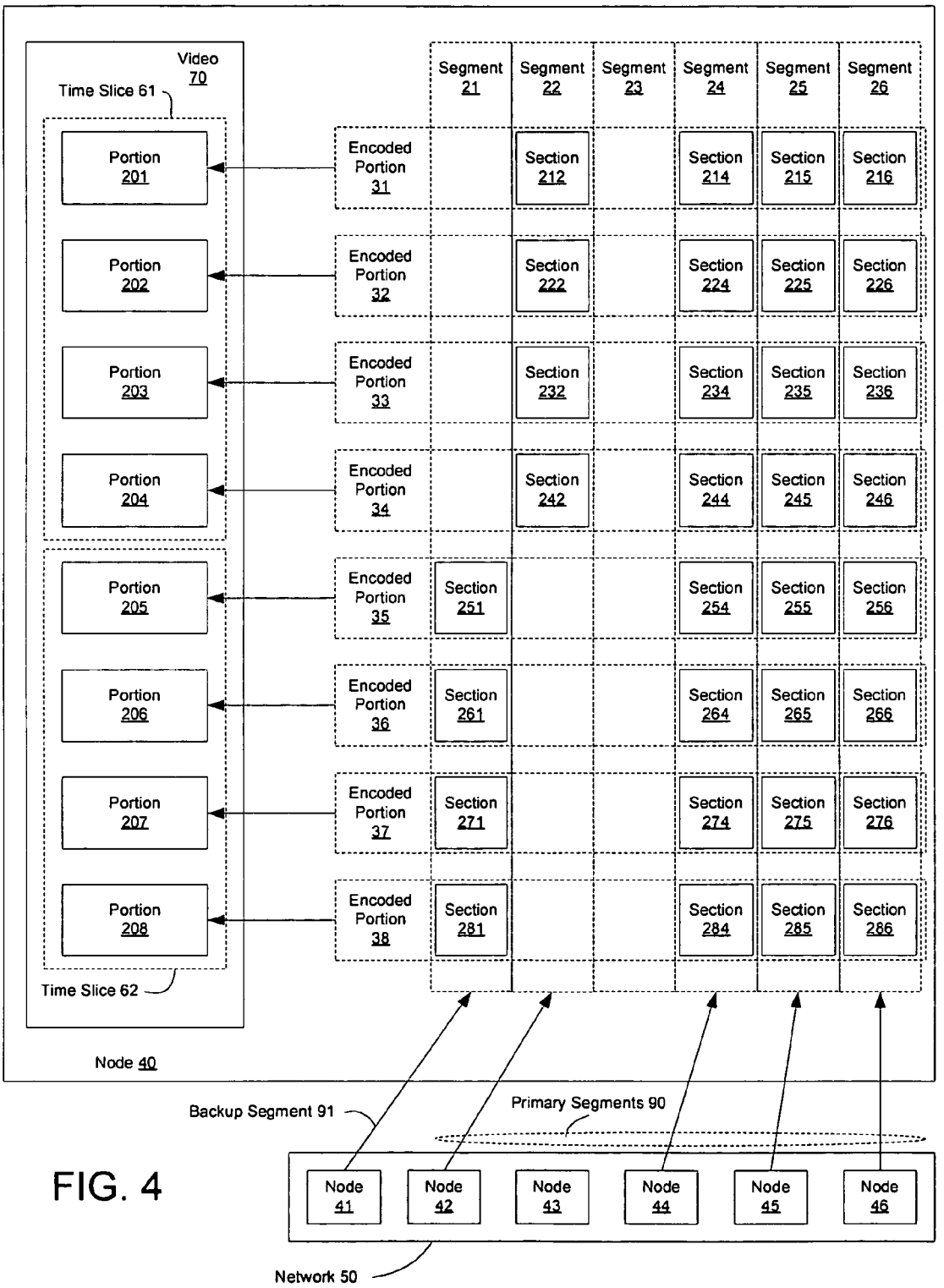

Video 70
Time Slice 61
Portion 201
Portion 202
Portion 203
Portion 204
Portion 205
Portion 206
Portion 207
Portion 208
Time Slice 62
Node 40
Segment 21
Segment 22
Segment 23
Segment 24
Segment 25
Segment 26
Encoded Portion 31
Encoded Portion 32
Encoded Portion 33
Encoded Portion 34
Encoded Portion 35
Encoded Portion 36
Encoded Portion 37
Encoded Portion 38
Section 212
Section 214
Section 215
Section 216
Section 222
Section 224
Section 225
Section 226
Section 232
Section 234
Section 235
Section 236
Section 242
Section 244
Section 245
Section 246
Section 251
Section 254
Section 255
Section 256
Section 261
Section 264
Section 265
Section 266
Section 271
Section 274
Section 275
Section 276
Section 281
Section 284
Section 285
Section 286
Backup Segment 91
Primary Segments 90
Node 41
Node 42
Node 43
Node 44
Node 45
Node 46
Network 50

FIG. 4

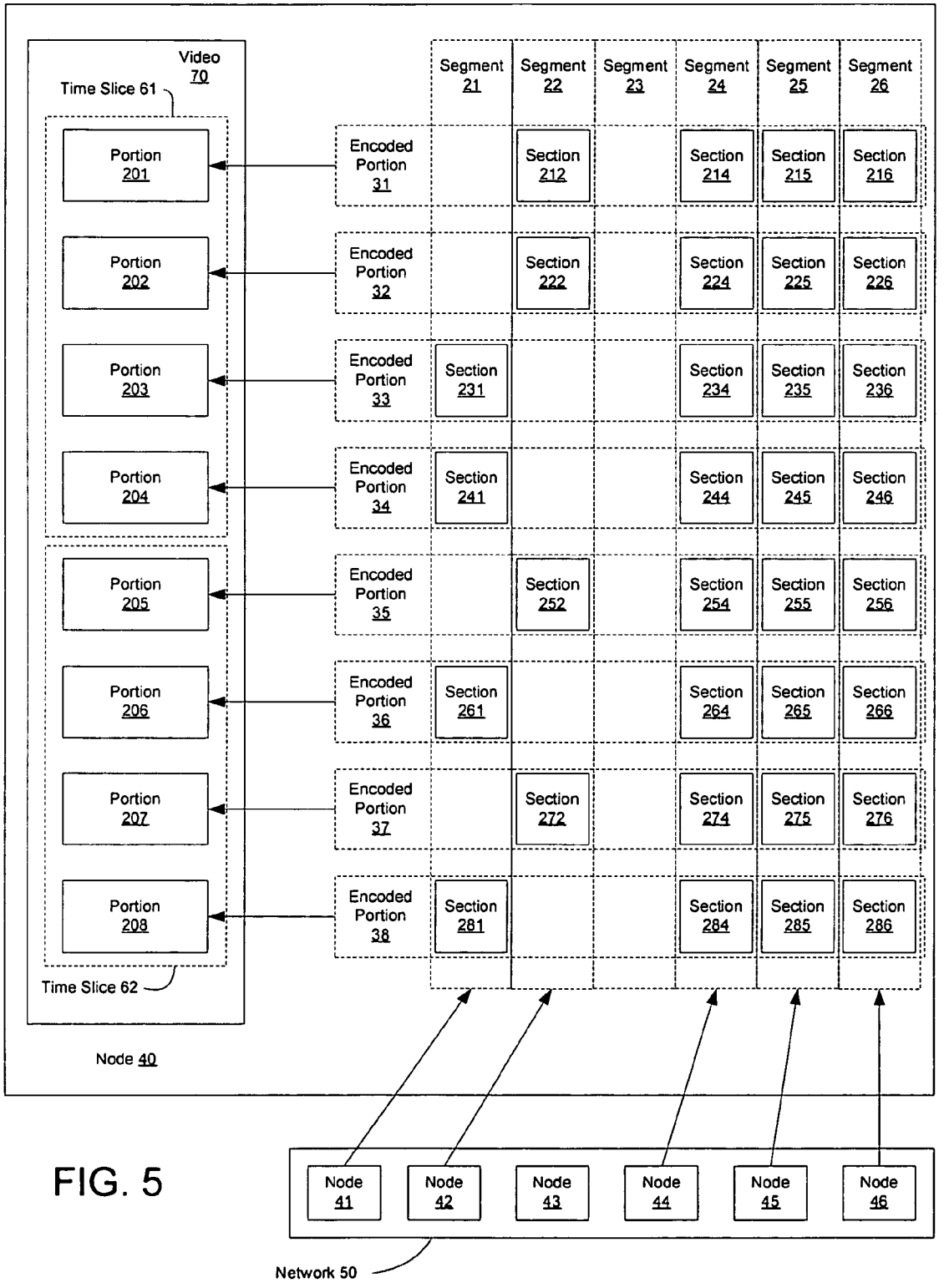

Video 70
Time Slice 61
Portion 201
Portion 202
Portion 203
Portion 204
Portion 205
Portion 206
Portion 207
Portion 208
Time Slice 62
Node 40
Segment 21
Segment 22
Segment 23
Segment 24
Segment 25
Segment 26
Encoded Portion 31
Encoded Portion 32
Encoded Portion 33
Encoded Portion 34
Encoded Portion 35
Encoded Portion 36
Encoded Portion 37
Encoded Portion 38
Section 212
Section 214
Section 215
Section 216
Section 222
Section 224
Section 225
Section 226
Section 231
Section 234
Section 235
Section 236
Section 241
Section 244
Section 245
Section 246
Section 252
Section 254
Section 255
Section 256
Section 261
Section 264
Section 265
Section 266
Section 272
Section 274
Section 275
Section 276
Section 281
Section 284
Section 285
Section 286
Node 41
Node 42
Node 43
Node 44
Node 45
Node 46
Network 50

FIG. 5

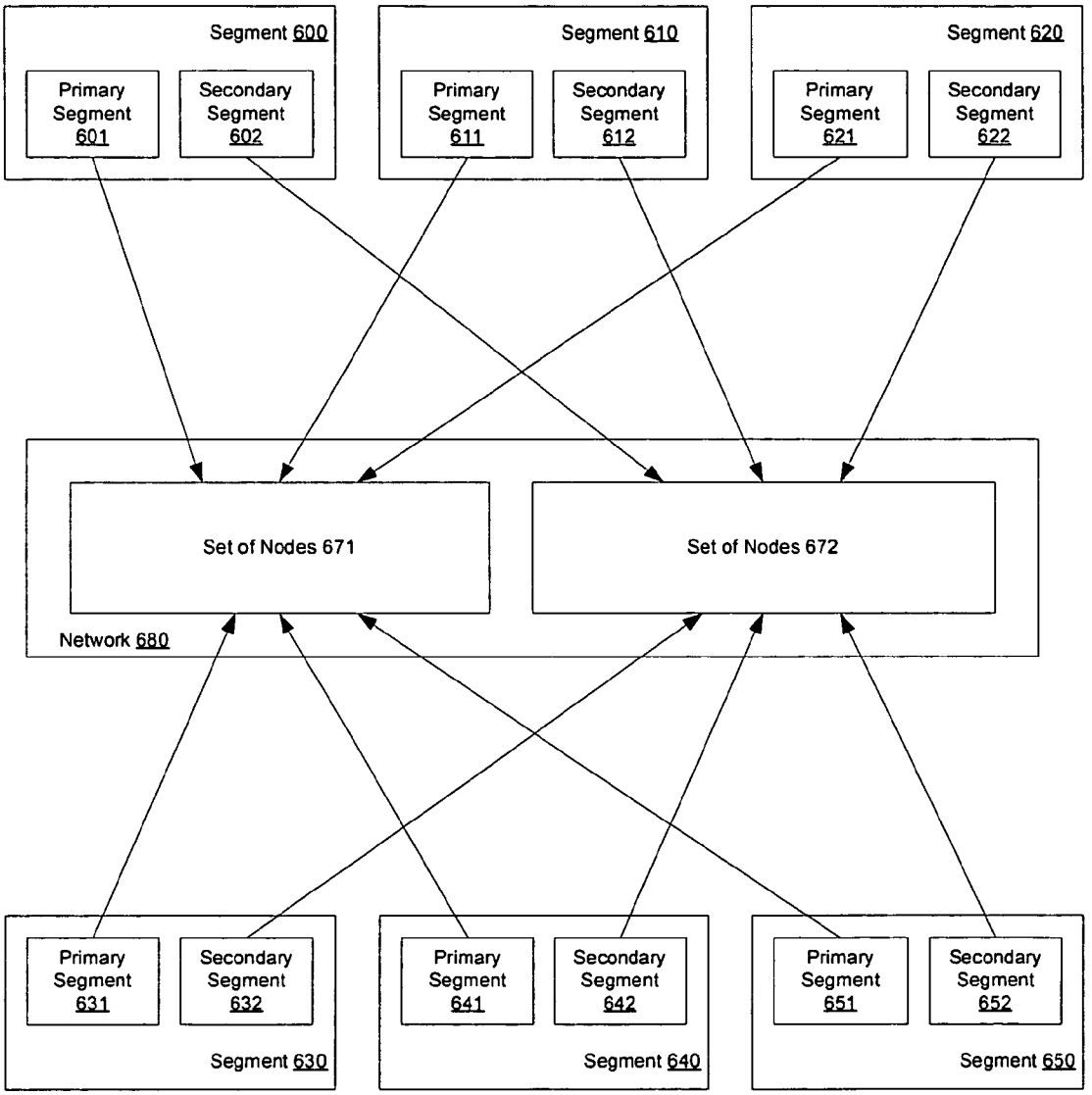

Segment 600
Primary Segment 601
Secondary Segment 602
Segment 610
Primary Segment 611
Secondary Segment 612
Segment 620
Primary Segment 621
Secondary Segment 622
Set of Nodes 671
Set of Nodes 672
Network 680
Primary Segment 631
Secondary Segment 632
Segment 630
Primary Segment 641
Secondary Segment 642
Segment 640
Primary Segment 651
Secondary Segment 652
Segment 650

FIG. 6

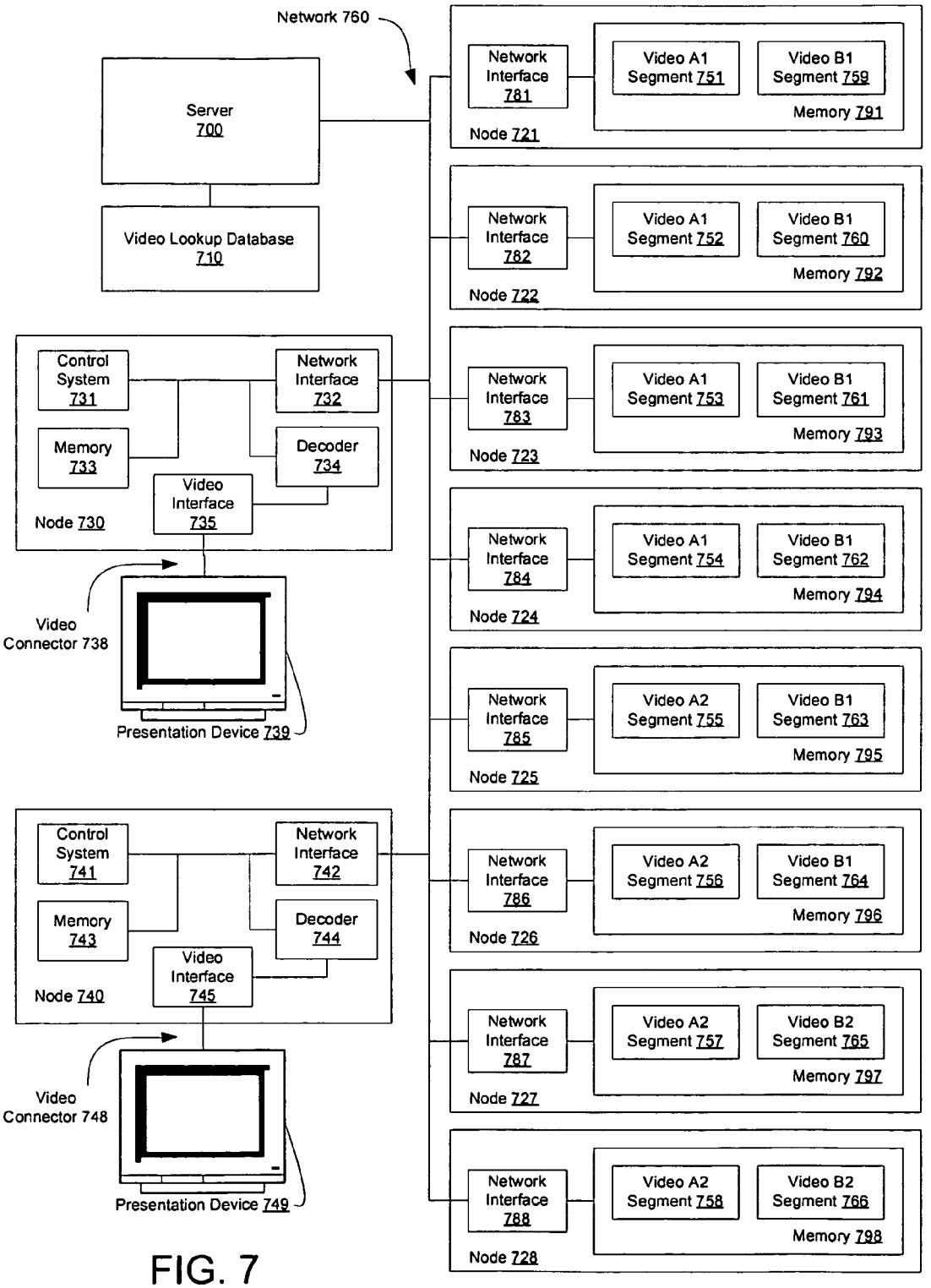

Network 760
Server 700
Video Lookup Database 710
Control System 731
Network Interface 732
Memory 733
Decoder 734
Video Interface 735
Node 730
Video Connector 738
Presentation Device 739
Control System 741
Network Interface 742
Memory 743
Decoder 744
Video Interface 745
Node 740
Video Connector 748
Presentation Device 749
Network Interface 781
Video A1 Segment 751
Video B1 Segment 759
Memory 791
Node 721
Network Interface 782
Video A1 Segment 752
Video B1 Segment 760
Memory 792
Node 722
Network Interface 783
Video A1 Segment 753
Video B1 Segment 761
Memory 793
Node 723
Network Interface 784
Video A1 Segment 754
Video B1 Segment 762
Memory 794
Node 724
Network Interface 785
Video A2 Segment 755
Video B1 Segment 763
Memory 795
Node 725
Network Interface 786
Video A2 Segment 756
Video B1 Segment 764
Memory 796
Node 726
Network Interface 787
Video A2 Segment 757
Video B2 Segment 765
Memory 797
Node 727
Network Interface 788
Video A2 Segment 758
Video B2 Segment 766
Memory 798
Node 728

FIG. 7

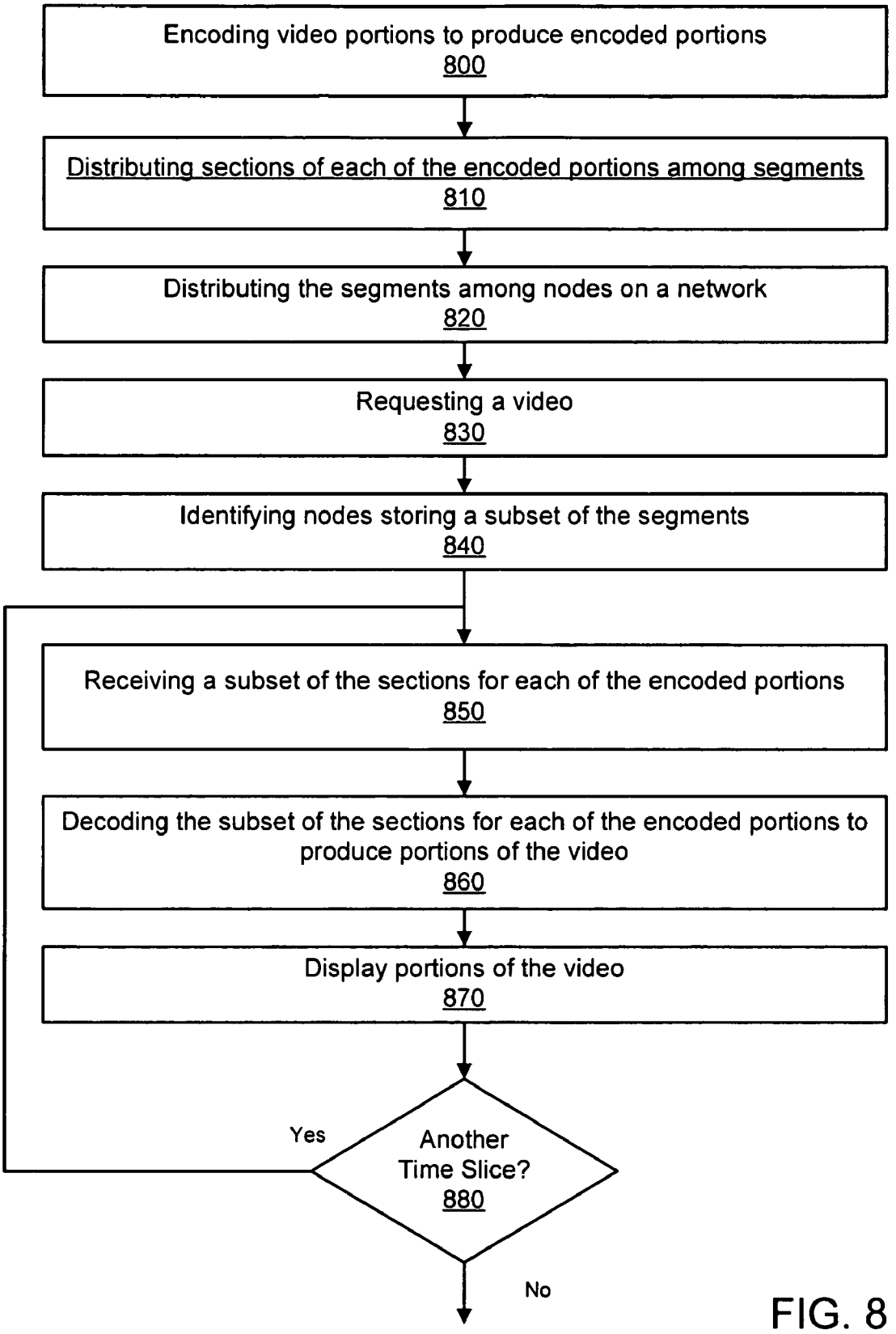

Encoding video portions to produce encoded portions
800
Distributing sections of each of the encoded portions among segments
810
Distributing the segments among nodes on a network
820
Requesting a video
830
Identifying nodes storing a subset of the segments
840
Receiving a subset of the sections for each of the encoded portions
850
Decoding the subset of the sections for each of the encoded portions to produce portions of the video
860
Display portions of the video
870
Another Time Slice?
880
Yes
No

FIG. 8

STREAMING VIDEO USING ERASURE ENCODING

BACKGROUND

1. Field

Embodiments described herein relates generally to the field of video systems. More particularly, the disclosure relates to a system, apparatus and method for streaming videos.

2. Description of the Related Art

Video on Demand (VOD) systems allow users to request and view videos over a network.

In some VOD systems, a user requests a video using a box (e.g., a set-top receiver) connected through a network to a server farm. In response to a video request, the server farm "streams" the selected video to the box. The video is presented to the user while the rest of the video is being downloaded. As the number of boxes in the network increases, the bandwidth capacity required at the server farm increases.

In other VOD systems, a video library is distributed among the boxes of multiple users. When a user requests a video using their box, the request is serviced over the network by one of the boxes that store the requested video. This peer-to-peer network distributes the bandwidth requirements across the boxes on the network. As the number of boxes in the network increases, the quantity of videos requested increases but the bandwidth capacity also increases since there are more boxes to service the video requests.

However, the capacity to serve a particular video is limited, since a predetermined number of copies of that video are distributed among a fixed number of boxes. Each box has limited bandwidth capacity to serve the video(s) stored in that box. Thus, the peer-to-peer configuration restricts the flexibility to concurrently deliver quantities of particular videos.

In other VOD systems, the entire video is downloaded to the box before it is presented on the user's video system. By lengthening the period over which the video is downloaded, the bandwidth requirements can be reduced whether using a centralized server or a peer-to-peer network. However, the longer download period increases the delay from the time the user requests a video to when that user can watch the requested video.

What is needed is a VOD system that allows a video to be watched soon after the request. What is also needed is a VOD system that allows more flexibility in terms of capacity to concurrently serve particular videos to multiple users. What is further needed is a VOD system that can scale in terms of the number of boxes being served while limiting the increase in bandwidth requirements.

SUMMARY

A system for streaming a movie on demand is described. According to one embodiment, portions of a movie are encoded into encoded portions each having sections, the sections for each encoded portion being distributed among segments. The system includes an apparatus including a network interface coupled to the one or more nodes; a control system coupled to the network interface and configured to initiate a movie request and communicate with the one or more nodes to receive a subset of the segments; and a decoder coupled to the network interface and configured to decode a subset of the sections so that less than all of the sections are used to play back the portions of the movie. A presentation device coupled to the apparatus is configured to present the portions in playing back (i) the movie in it's entirety, and (ii) each portion of the movie, in its entirety, without using all of the sections of that portion.

An apparatus for streaming a movie on demand is described including a network interface; a control system coupled to the network interface and configured to send a movie request and communicate with one or more nodes; a decoder coupled to the network interface and configured to decode a subset of a set of sections so that less than all of the sections are used to play back a portion of the movie, the subset of the set of sections for each of the set of encoded portions being assembled from a subset of a plurality of segments; and a video interface coupled to the decoder and configured to transmit the set of portions in playing back (i) the movie in its entirety, and (ii) each portion of the movie, in its entirety, without using all of the sections of that portion are assembled.

A method of processing a movie over a network is described including encoding each of a plurality of portions of the movie to generate a plurality of encoded portions each having a plurality of sections; distributing each plurality of sections among a plurality of segments; requesting the movie; identifying one or more nodes storing a subset of the plurality of segments; receiving a subset of the plurality of sections for each of the plurality of encoded portions from the one or more nodes; and decoding each subset of the plurality of sections so that less than all of the sections are used to play back the movie. A particular portion of the movie is played back without using all of the sections for that particular portion.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features, aspects, and advantages of the present invention will become better understood with regard to the following description, appended claims, and accompanying drawings where:

FIG. **1** illustrates a system for streaming a video according to one embodiment.

FIG. **2** shows a block diagram of one embodiment of an encoding system.

FIG. **3** shows a block diagram of one embodiment of a decoding system.

FIG. **4** shows a block diagram of a decoding system using primary segments and a backup segment according to one embodiment.

FIG. **5** shows a block diagram of one embodiment of a decoding system using different subsets of the segments for some encoded portions.

FIG. **6** shows a block diagram of the distribution of primary and secondary segments according to one embodiment.

FIG. **7** illustrates a system using primary and secondary segments for streaming a video according to one embodiment.

FIG. **8** is a flow chart that that he think illustrates a method of streaming a video according to one embodiment.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Described below is a system and method for streaming video. Throughout the description, for the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be apparent, however, to one skilled in the art that the present invention may be practiced without some of these specific details. In other instances, well-known structures and

devices are not shown in the figures to avoid obscuring the underlying principles of the present invention.

Embodiments may be implemented in a video on demand (VOD) system as illustrated generally in FIG. **1**. The system includes nodes coupled through a network **160** to a server **100** that has a video lookup database **110**. In one embodiment, the server **100** is operated by a VOD service provider.

Users of the video on demand service access the service through the network **160**. A node **130** has a control system **131**, a memory **133** and a decoder **134** coupled through a network interface **132** to the network **160**. The node **130** has a video interface **135** coupled to the decoder **134** and coupled through a video connector **138** to a presentation device **139**. In some embodiments, the node **130** is a box supplied by the VOD service provider. In other embodiments, the node **130** is a personal computer.

A user can request a video A, for example, through the control system **131**. The user can submit that request using a remote control or a keyboard, for example. In response, the control system **131** initiates a video request through the network interface **132** onto the network **160**. The server **100** is configured to respond to video requests from the nodes on the network **160**. When a request is received, the server **100** accesses the video lookup database **110** to determine which of the nodes on the network **160** store segments associated with video A and are available to serve the segments to the node **130**. In one embodiment, the server **100** allocates the nodes that are least likely to be needed for a subsequent video request based on, for example, the popularity of videos associated with the other segments stored on each node.

As an example, the video A is associated with six segments, a segment **151**, a segment **152**, a segment **153**, a segment **154**, a segment **155**, and a segment **156**. In one embodiment, any four of the six segments can be used to generate the video A. The relationship between the videos and the segments are described in more detail with reference to subsequent figures.

For example, the server **100** can allocate a node **121**, a node **122**, a node **123** and a node **124** in response to the request for the video A from the node **130**. The node **121** has a memory **191** that is coupled to the network **160** through a network interface **181**. The memory **191** stores the segment **151** corresponding to the video A and a segment **159** corresponding to a video C. A node **122** has a memory **192** that is coupled to the network **160** through a network interface **182**. The memory **192** stores the segment **152** corresponding to the video A and a segment **160** corresponding to the video C. A node **123** as a memory **193** that is coupled to the network **160** through a network interface **183**. The memory **193** stores the segment **153** corresponding to the video A and a segment **161** corresponding to the video B. A node **124** has a memory **194** that is coupled to the network **160** through a network interface **184**. The memory **194** stores the segment **154** corresponding to the video A and a segment **162** corresponding to the video B.

After receiving the allocation of the nodes from the server **100**, the network interface **132** communicates with the network interface **181** to receive the segment **151**, the network interface **132** communicates with the network interface **182** to receive the segment **152**, the network interface **132** communicates with the network interface **183** to receive the segment **153** and the network interface **132** communicates with the network interface **184** to receive the segment **154**.

In one embodiment, the download bandwidth of the node **140** is at least four times the upload bandwidth of a typical node in the network **160**. Thus, the network interface **132** can download all four segments from the network **160** at the combined rate that the network interface **181**, the network interface **182**, the network interface **183** and a network interface **184** can upload those four segments to the network **160**. In one embodiment, the number of segments is chosen to be such that the concurrent download of all necessary segments is fast enough to enable playback of video in real time. In one embodiment, multiple segments can be downloaded from the same node if that node has enough upstream bandwidth to concurrently upload the multiple segments at the required rate.

The decoder **134** receives the four segments and generates the video according to methods described with reference to subsequent figures. A video interface **135** is coupled to receive the video from the decoder **134** and transmit the video through a video connector **138** to a presentation device **139**. In one embodiment, the presentation device **139** is a television. Alternatively, the presentation device **139** is another device capable of audiovisual representation of the video. In some embodiments, the presentation device **139** is only capable of presenting video without sound. In other embodiments, the presentation device **139** is only capable of presenting sound without video.

Another user has a node **140** including a control system **141**, a memory **143** and a decoder **144** coupled to a network interface **142** on the network **160**. The node **140** has a video interface **145** coupled to the decoder **144** and coupled to a video connector **148** to a presentation device **149**.

A user can request, for example, a video B through the control system **141**. In response, the control system **141** initiates a video request through the network interface **142** onto the network **160**. When a request is received, the server **100** accesses the video lookup database **110** to determine which of the nodes on the network **160** store segments associated with the video B and are available to serve the segments to the node **130**.

The video B is associated with six segments: a segment **161**, a segment **162**, a segment **163**, a segment **164**, a segment **157** and a segment **158**. In one embodiment, any four of the six segments can be used to generate the video B. If the request for video B happens while the node **123** and the node **124** are still serving the segments for video A as described above, the node **123** and the node **124** are temporarily unavailable to serve the segment **161** and the segment **162**, respectively, for video B.

In response to the request for video B, the server **100** can allocate a node **125**, a node **126**, a node **127** and a node **128**. The node **125** has a memory **195** that is coupled to the network **160** through a network interface **185**. The memory **195** stores the segment **155** corresponding to the video A and the segment **163** corresponding to the video B. The node **126** has a memory **196** that is coupled to the network **160** through a network interface **186**. The memory **196** stores a segment **156** corresponding to the video A and the segment **164** corresponding to the video B. A node **127** has a memory **197** that is coupled to the network **160** through a network interface **187**. The memory **197** stores a segment **157** corresponding to the video B and the segment **165** corresponding to the video C. A node **128** has a memory **198** that is coupled to the network **160** through a network interface **188**. The memory **198** stores a segment **158** corresponding to the video B and the segment **166** corresponding to the video C.

After receiving the allocation of the nodes from the server **100**, the network interface **142** requests the segments from the nodes. The network interface **142** communicates with the network interface **185** to receive the segment **151**. The network interface **142** communicates with the network interface **186** to receive the segment **152**. The network interface **142** communicates with the network interface **187** to receive the

segment **153**. And the network interface **142** communicates with the network interface **188** to receive the segment **154**.

The decoder **144** receives the four segments and decodes the four segments to generate the video according to methods described with reference to subsequent figures. A video interface **145** is coupled to receive the video from the decoder **144** and transmit the video through a video connector **148** to a presentation device **149**. The presentation device **149** can be a device capable of audiovisual representation of the video.

Nodes **121-128** are illustrated to emphasize components used to serve segments in response to a video request according to the example video requests described above. In some embodiments, each of these nodes has a control system, decoder and video interface to provide the functionality described with reference to the node **130**, for example. In some embodiments, the node **130** is configured to provide similar functionality as described with reference to the node **121**, for example.

The example illustrated uses six independent segments. In other embodiments, a different number of segments may be used. In some embodiments, the same segment may be duplicated on multiple nodes to allow for more concurrent requests for the same video. In this example, any four of the six independent segments can be used to generate the video. In other embodiments, a different number of independent segments may be required. It will be apparent to one skilled in the art that duplicate segments cannot be used to establish the minimum number of segments to generate the video.

Because only some of the segments are required to generate the video, there is quite a bit of flexibility in terms on selecting combinations of nodes that can generate the video. As the number of segments increases so does the number of combinations of segments that can be used to generate the video.

FIG. **2** is a block diagram illustrating one embodiment of an encoding system of the present invention.

A video **70** is the source of the video for the encoding process. The process is not limited to any particular video format. In some embodiments, the video **70** format can be Digital Video (DV) Encoder Type 1, DV Encoder Type 2, MPEG-1 (Moving Picture Experts Group format 1), MPEG-2, MPEG-4, or Real Video.

In one embodiment, the video **70** is processed as a sequence of time slices. The time slices are blocks of audiovisual data each including several portions. Two time slices are shown for illustrative purposes. A time slice **61** includes a portion **201**, a portion **202**, a portion **203** and a portion **204**. A time slice **62** includes a portion **205**, a portion **206**, a portion **207** and a portion **208**.

In one embodiment, each portion is encoded using an erasure code, such as a Hamming code, Reed-Solomon code, or Tornado code. An erasure code transforms data of n sections into encoded data with more than n sections such that the original data can be generated from any subset of the sections of the encoded data that include the minimum number of sections for that code. Strict subsets of the encoded data are any combination of less than all the sections of the encoded data. Rateless erasure codes can transform data of n sections into encoded data of an arbitrary number of sections. Erasure codes can also provide an error correcting function allowing the original data to be recovered despite a limited number of bit errors within the sections of the encoded message. In another embodiment, the erasure code used can be the identity function, i.e., the encoded segments are exactly identical to the original segments.

In the illustrated example, each portion is encoded into encoded portions having six blocks of which any four blocks can be used to generate the portion. The portion **201** is encoded into an encoded portion **31** having a section **211**, a section **212**, a section **213**, a section **214**, a section **215** and a section **216**. The portion **202** is encoded into an encoded portion **32** having a section **221**, a section **222**, a section **223**, a section **224**, a section **225** and a section **226**. The portion **203** is encoded into an encoded portion **33** having a section **231**, a section **232**, a section **233**, a section **234**, a section **235** and a section **236**. The portion **204** is encoded into an encoded portion **34** having a section **241**, a section **242**, a section **243**, a section **244**, a section **245** and a section **246**.

The portion **205** is encoded into an encoded portion **35** having a section **251** a section **252**, a section **253**, the section **254**, section **255** and a section **256**. The portion **206** is encoded into encoded portion **36** having a section **261**, a section **262**, a section **263**, a section **264**, a section **265** and a section **266**. The portion **207** is encoded into an encoded portion **37** having a section **271**, a section **272**, a section **273**, a section **274**, a section **275** and a section **276**. The portion **208** is encoded into an encoded portion **38** having a section **281**, a a section **282**, a section **283**, a section **284**, a section **285** and a section **286**.

A segment **21** is generated by assembling the section **211**, the section **221**, the section **231**, the section **241**, the section **251**, the section **261**, the section **271** and the section **281**. A segment **22** is generated by assembling the section **212**, the section **222**, the section **232**, the section **242**, the section **252**, the section **262**, the section **272** and the section **282**. A segment **23** is generated by assembling the section **213**, the section **223**, the section **233**, the section **243**, the section **253**, the section **263**, the section **273** and the section **283**. A segment **24** is generated by assembling the section **214**, the section **224**, the section **234**, the section **244**, the section **254**, the section **264**, the section **274** and the section **284**. A segment **25** is generated by assembling the section **215**, the section **225**, the section **235**, the section **245**, the section **255**, the section **265**, the section **275** and the section **285**. A segment **26** is generated by assembling the section **216**, the section **226**, the section **236**, the section **246**, the section **256**, the section **266**, the section **276** and the section **286**.

In this illustration, two time slices are shown, each with four portions. However, the same technique can be applied to an arbitrary number of time slices using more or less portions. Furthermore, the encoding process may generate more or less sections according to well-known methods.

The segments are distributed over a network **50** to be stored among a set of nodes. In one embodiment, these nodes are configured as described with reference to the block diagram of the node **130** shown in FIG. **1**. The segment **21** is distributed to a node **41**. The segment **22** is distributed to a node **42**. The segment **23** is distributed to a node **43**. The segment **24** is distributed to a node **44**. The segment **25** is distributed to a node **45** and the segment **26** is distributed to a node **46**.

FIG. **3** is a block diagram illustrating one embodiment of a decoding system of the present invention.

In one embodiment, each portion is decoded using an erasure code. Any four of the six segments can be used to generate the video **70**. A node **40** requests the video and four nodes are assigned to deliver the segments. In this example, the node **42**, the node **44**, the node **45** and the node **46** transmit the segment **22**, the segment **24**, the segment **25** and the segment **26**, respectively, over the network **50** to the node **40**.

In one embodiment, each portion is decoded using an erasure code. The section **212**, the section **214**, the section **215** and the section **216** of the encoded portion **31** are decoded to generate the portion **201**. The section **222**, the section **224**, the section **225** and the section **226** of the encoded portion **32** is

decoded to generate the portion **202**. The section **232**, the section **234**, the section **235** and a section **236** of the encoded portion **33** are decoded to generate the portion **203**. The section **242**, the section **244**, the section **245** and the section **246** of the include portion **204** are decoded to generate the portion **204**. The portion **201**, the portion **202**, the portion **203** and the portion **204** are assembled to generate the time slice **61**.

The section **252**, the section **254**, the section **255** and the section **256** of the encoded portion **35** are decoded to generate the portion **205**. The section **262**, the section **264**, the section **265** and the section **266** of the encoded portion **36** are decoded to generate the portion **206**. The section **272**, the section **274**, the section **275** and the section **276** of the include portion of the seven are decoded to generate the portion **207**. The section **282**, the section **284**, the section **285** and a section **286** of the encoded portion **38** are decoded to generate the portion **208**. The portion **205**, the portion **206**, the portion **207** and the portion **208** are assembled to generate the time slice **62**.

FIG. **4** is a block diagram illustrating another embodiment of a decoding system of the present invention.

In one embodiment, a set of primary segments **90** and a backup segment **91** are allocated in response to a video request. The backup segment **91** can be used to substitute for one of the primary segments **90** in response to a failure, for example, of a node transmitting one of the primary segments **90**. In other embodiments, additional backup segments can be allocated to a video request.

In this example, any four of the six segments can be used to generate the video **70**. The node **40** requests a video. The set of primary segments **90** allocated to the video request include the segment **22**, the segment **24**, the segment **25** and a segment **26**. The backup segment **91** allocated to the video request is the segment **21**. The node **42**, the node **44**, the node **45** and the node **46** transmit the segment **22**, the segment **24**, the segment **25** and the segment **26**, respectively, over the network **50** to the node **40**.

The section **212**, the section **214**, the section **215**, the section **216** of the encoded portion **31** are decoded to generate the portion **201**. The section **222**, the section **224**, the section **225** and the section **226** of the encoded portion **32** is decoded to generate the portion **202**. The section **232**, the section **234**, the section **235** and the section **236** of the encoded portion **33** are decoded to generate the portion **203**. The section **242**, the section **244**, the section **245** and the section **246** of the include portion **204** are decoded to generate the portion **204**. The portion **201**, the portion **202**, the portion **203** and the portion **204** are assembled to generate the time slice **61**.

In this example, the backup segment **91** replaces the segment **22** after time slice **61** is processed. The backup segment can be used instead of one of the primary segments when, for example, the node transmitting one of the primary segments **90** malfunctions, is disconnected from the network, or loses power. The node **42** stops transmitting the segment **22**. In response, the node **41** starts transmitting the segment **21** over the network **50** to the node **40**.

The section **251**, the section **254**, the section **255** and the section **256** of the encoded portion **35** are decoded to generate the portion **205**. The section **261**, the section **264**, the section **265** and the section **266** of the encoded portion **36** are decoded to generate the portion **206**. The section **271**, the section **274**, the section **275** and the section **276** of the include portion of the seven are decoded to generate the portion **207**. The section **281**, the section **284**, the section **285** and the section **286** of the encoded portion **38** are decoded to generate the portion **208**. The portion **205**, the portion **206**, the portion **207** and the portion **208** are assembled to generate and the time slice **62**.

FIG. **5** is a block diagram illustrating another embodiment of a decoding process of the present invention.

The node **40** requests a video. In this example, a set of segments are allocated to a video request and the subset of the set of segments used for at least two of the portions in a time slice are different. In one embodiment, any four of the six segments can be used to generate the video **70**. In this example, the node **44**, the node **45** and the node **46** transmit the segment **24**, the segment **25** and the segment **26**, respectively, over the network **50** to the node **40**.

The section **212**, the section **214**, section **215** and section **216** of the encoded portion **31** are decoded to generate the portion **201**. The section **222**, the section **224**, the section **225** in the section **226** of the include portion **32** or decoded to generate the portion **202**. The section **231**, the section **234**, the section **235** and section **236** of the include portion of the three are decoded to generate the portion **203**. The section **241**, the section **244**, the section **245** and the section **246** of the include portion **34** decoded to generate the portion **204**. The portion **201**, the portion **202**, the portion **203** and the portion **204** are assembled to generate the time slice **61**.

The section **252**, the section **254**, the section **255** and the section **256** of the encoded portion **35** are decoded to generate the portion **205**, the section **261**, the section **264**, the section **265** and a section **266** of encoded portion **36** are decoded to generate the portion **206**. The section **272**, the section **274**, the section **275** in the section **276** of the include portion **37** are decoded to generate the portion **207**. **285** in the section **286** of the include portion **38** are decoded to generate the portion **208**. The portion **205**, the potion **206**, the portion **207** and the portion **208** are assembled to generate the time slice **62**.

FIG. **6** shows a block diagram of the distribution of primary and secondary segments according to one embodiment of the invention.

In one embodiment, each of the segments associated with a video are split into a primary segment and a secondary segment. The primary segment corresponds to the first half of the playback duration of the video. The secondary segment corresponds to the second half of the playback duration of the video.

A segment **600** includes a primary segment **601** and a secondary segment **602**. A segment **610** includes the primary segment **611** and a secondary segment **612**. A segment **620** includes a primary segment **621** and a secondary segment **622**. A segment **630** includes a primary segment **631** and a secondary segment **632**. A segment **640** includes a primary segment **641** and a secondary segment **642**. A segment **650** includes a primary segment **651** and a secondary segment **652**.

The primary segment **601**, the primary segment **611**, the primary segment **621**, the primary segment **631**, the primary segment **641** in the primary segment **651** are distributed over a network **680** to a set of nodes **671**. The secondary segment **602**, the secondary segment **612**, the secondary segment **622**, the secondary segment **632**, the secondary segment **642** and a secondary segment **652** are distributed over a network **680** a set of nodes **672**. In one embodiment, the set of nodes **671** is not disjoint from the set of nodes **672**.

Nodes requesting a streaming video corresponding to the first half of the video are assigned nodes from the set of nodes **671**. Nodes requesting a streaming video corresponding to the second half of the video are assigned nodes from the set of nodes **672**. Once a node completes viewing the first half of the video, it is assigned nodes from the set of nodes **672** so that it can start viewing the second half. This assignment is done in advance to ensure that there is no interruption in movie watching as a node transitions from the first half to the second half.

The division of segments into primary and secondary segments can, in the best case, double the peak capacity of concurrent streams of that video for the same average storage used per node. Observe that, at any given point in time, -half the nodes receiving a particular video could be streaming the first half of the video from the set of nodes **671** and half the nodes receiving that video could be streaming the second half of that video from the set of nodes **672**. Since different nodes are streaming each half of the video, the peak capacity of concurrent streams of that video doubles as compared to the case in which the whole video is served by the same node.

Approximately the same storage capacity is used, allowing for some overhead, since twice as many nodes store half of the video as compared to the case where the whole video is served by the same node. Since less to space is taken for each video stored on a particular node, more video selections can be stored on a node having a given memory capacity. This allows for more flexibility in the allocation of nodes in response to video requests.

In other embodiments, the video is broken into three or more periods and segments corresponding to each of the periods are distributed among three or more sets of nodes. In some embodiments, breaking the video into more periods can further increase flexibility in the allocation of nodes in response to video requests and the peak capacity of concurrent streams of a particular video.

Embodiments of the invention can be implemented in a VOD system using primary and secondary segments as illustrated generally in FIG. **7**. The system includes nodes coupled through a network **760** to a server **700** that has a video lookup database **710**.

Users of the video on demand service access the service through the network **760**. A node **730** has a control system **731**, a memory **733** and a decoder **734** coupled to a network interface **732** to the network **760**. The node **730** has a video interface **735** coupled to the decoder **734** and coupled through a video connector **738** to a presentation device **739**.

For example, a user can request a video A through the control system **731**. In response, the control system **731** initiates a video request for the first period of the video A through the network interface **732** onto the network **760**. The server **700** is configured to respond to video requests from the nodes on the network **760**. When a request is received, the server **700** accesses the video lookup database **710** to determine which of the nodes on the network **760** store segments associated with the first period of the video A and are available to serve the segments to the node **730**.

The server can allocate a node **121**, a node **122**, a node **123** and a node **124**, for example, to serve the first period of the video. The node **721** has a memory **791** that is coupled to the network **760** through a network interface **781**. The memory **791** stores the segment **751** corresponding to the first period of video A and a segment **759** corresponding to first period of video B. A node **722** has a memory **792** that is coupled to the network **760** through a network interface **782**. The memory **792** stores the segment **752** corresponding to second period of the video A and a segment **760** corresponding to first period of the video B. A node **723** as a memory **793** that is coupled to the network **760** through a network interface **783**. The memory **793** stores the segment **763** corresponding to the second period of the video A and a segment **761** corresponding to the second period of the video B. A node **724** has a memory **794** that is coupled to the network **760** through a network interface **784**. The memory **794** stores the segment **754** corresponding to the second period of the video A and a segment **762** corresponding to the first period of the video B.

After receiving the allocation of the nodes from the server **700**, the network interface **732** communicates with the network interface **781** to receive the segment **751**, communicates with the network interface **782** to receive the segment **752**, communicate with the network interface **783** to receive the segment **753** and communicates with the network interface **784** to receive the segment **754**.

The decoder **734** receives the four segments and generates the video according to methods described with reference to other figures. A video interface **735** is coupled to receive the video from the decoder **734** and transmit the video through a video connector **738** and to a presentation device **739**. In one embodiment, the presentation device **739** is a television. Alternatively, the presentation device **739** is another device cable of audiovisual representation of the video.

When streaming the first period of video A is almost complete, the control system **731** initiates a video request for the second period of video A through the network interface **732** onto the network **760**. The server **700** accesses the video lookup database **710** to determine which of the nodes on the network **760** store segments associated with the second period of the video A and are available to serve the segments to the node **730**.

The server can allocate a node **125**, a node **126**, a node **127** and a node **128**, for example, to serve the first period of the video. The node **721** has a memory **795** that is coupled to the network **760** through a network interface **785**. The memory **795** stores the segment **755** corresponding to the second period of video A and a segment **763** corresponding to the first period of video B. A node **726** has a memory **796** that is coupled to the network **760** through a network interface **786**. The memory **796** stores the segment **756** corresponding to second period of the video A and a segment **764** corresponding to first period of the video B. A node **727** has a memory **797** that is coupled to the network **760** through a network interface **787**. The memory **797** stores the segment **765** corresponding to the second period of the video A and a segment **765** corresponding to the second period of the video B. A node **728** has a memory **798** that is coupled to the network **760** through a network interface **788**. The memory **798** stores the segment **758** corresponding to the second period of the video A and a segment **766** corresponding to the second period of the video B.

After receiving the allocation of the nodes from the server **700**, the network interface **732** communicates with the network interface **785** to receive the segment **755**, communicates with the network interface **786** to receive the segment **756**, communicate with the network interface **787** to receive the segment **757** and communicates with the network interface **788** to receive the segment **758**. The nodes **721-725** are now released to be available for allocation to stream another video as the newly allocated nodes are streaming the second portion of the video A to the node **730**.

The decoder **734** receives the four segments and generates the video. The video is transmitted through the video interface **735** and through the video connector **738** to the presentation device **739**.

A node **740** has a control system **741**, a memory **743** and a decoder **744** coupled to a network interface **742** in the network **760**. The node **740** has a video interface **745** coupled to the decoder **744** and coupled to a video connector **748** to a presentation device **749**.

Other users of the VOD service can concurrently access the service through the network **760**. A node **740** has a control system **741**, a memory **743** and a decoder **744** coupled to a network interface **742** to the network **760**. The node **740** has

a video interface **745** coupled to the decoder **744** and coupled through a video connector **748** to a presentation device **749**.

The user can request a video A, for example, through the control system **141**. In response, the control system **141** initiates a video request through the network interface **142** onto the network **160**. When a request is received, the server accesses the video lookup database **110** to determine which of the nodes on the network **160** store segments associated with first period of the video A and are available to serve the segments to the node **140**. For example, the server **700** can allocate a node **721**, a node **722**, a node **723** and a node **724** to respond to the request for the first period of video A from the node **130**.

After receiving the allocation of the nodes from the server **700**, the network interface **742** communicates with the network interface **781** to receive the segment **751**, communicates with the network interface **782** to receive the segment **752**, communicate with the network interface **783** to receive the segment **753** and communicates with the network interface **784** to receive the segment **754**. The decoder **734** receives the four segments and generates the video according to methods described with reference to subsequent figures. A video interface **735** is coupled to receive the video from the decoder **734** and transmit the video through a video connector **738** and to a presentation device **739**.

FIG. **8** is a flow chart that illustrates one embodiment of a method in accordance with the disclosure herein.

In step **800**, the video portions are encoded to generate encoded portions each having multiple sections. In one embodiment, the encoding process is performed using an erasure code, such as a Hamming code, a Reed-Solomon code or a Tornado code.

In step **810**, the sections of each of the encoded portions are distributed among a set of segments.

In step **820**, the segments are distributed among nodes on a network. In some embodiments, the encoding process is performed as illustrated with reference to FIG. **2**.

In step **830** a video is requested. In one embodiment, the node requests the video in response to a user request submitted through a remote control or keyboard.

In step **840** the nodes storing a subset of the segments are identified. In one embodiment, a server accesses a video lookup database to determine which of the nodes on the network store segments associated with the requested video and are available to serve the segments. In one embodiment, the server allocates the nodes that are least likely to be needed for a subsequent video request based on, for example, the popularity of videos associated with the other segments stored on each node.

In step **850**, a subset of the sections for each of the encoded portions are received.

In step **860**, the subset of the sections for each of the encoded portions is decoded to generate portions of the video. In some embodiments, the decoding process is performed as illustrated with reference to FIGS. **3**, **4** and **5**.

In step **870**, the portions of the video are presented. In one embodiment, the video is displayed on a television or other device capable of audiovisual representation. In some embodiments, the video is presented without sound. In other embodiments, the video is presented without images.

In step the **880**, it is determined whether another time slice is available. If yes, step **850** is performed to process subsequent time slices. If no, the flow chart is completed.

What is claimed is:

1. A system for streaming a movie on demand over a network comprising:

a server configured to: (i) encode a plurality of portions of the movie to a plurality of encoded portions so that each encoded portion has a plurality of sections, (ii) generate a plurality of segments, each segment comprising a section of some of the plurality of encoded portions, and (iii) distribute the plurality of segments to some of a plurality of nodes, wherein the plurality of portions corresponds to a time slice of the movie, and wherein the number of the plurality of portions of the time slice is approximately equal to a ratio of a predetermined download bandwidth to a predetermined upload bandwidth;

an apparatus comprising:

a network interface coupled to the network;

a control system coupled to the network interface and configured to:

(i) initiate a request for the movie, and (ii) communicate with one or more nodes of the plurality of nodes to receive a subset of the plurality of segments; and

a decoder coupled to the network interface and configured to decode a subset of the plurality of sections so that less than all of the plurality of sections are used to play back the portions of the movie;

wherein the apparatus enables (i) the movie to be played back in its entirety, and (ii) each portion of the movie to be played back in its entirety, without using all of the plurality of sections of that portion; and

a presentation device coupled to the apparatus, the presentation device being configured to display the plurality of portions of the movie for play back;

wherein the server is further configured to, in response to the request for the movie, identify the one or more nodes of the plurality of nodes that store the subset of the plurality of sections in order to enable the control system of the apparatus to receive the subset of the plurality of segments from the one or more nodes.

2. The system of claim **1**, wherein the apparatus further comprises a memory configured to store a second plurality of segments corresponding to a plurality of movies, and wherein the control system is further configured to transfer one of the second plurality of segments through the network in response to a request.

3. The system of claim **1**, wherein the movie is encoded using an erasure code.

4. The system of claim **1**, wherein each section from the subset of the plurality of sections is from a respective segment from the subset of the plurality of segments.

5. The system of claim **1**, wherein at least two sections of the subset of the plurality of sections are from different subsets of the plurality of segments.

6. The system of claim **1**, wherein the plurality of portions of the movie comprise a first plurality of portions corresponding to a first period of the movie and a second plurality of portions corresponding to a second period of the movie, and wherein the plurality of encoded portions comprises a first plurality of encoded portions corresponding to the first period of the movie and a second plurality of encoded portions corresponding to the second period of the movie.

7. The system of claim **6**, wherein the subset of the plurality of segments comprises a plurality of primary segments and a backup segment, all of the plurality of sections corresponding to the first period being from the plurality of primary segments and at least one of the plurality of sections corresponding to the second period being from the backup segment.

8. The system of claim **7**, wherein the control system of the apparatus is further configured to use the backup segment in response to a fault in one of the one or more nodes supplying one of the plurality of primary segments.

9. The system of claim 6, wherein the subset of the plurality of segments comprises a plurality of primary segments and a plurality of secondary segments, the subset of the plurality of sections from the first plurality of encoded portions being from the plurality of primary segments and the subset of the plurality of sections from the second plurality of encoded portions being from the plurality of secondary segments.

10. The system of claim 9, wherein the first period and the second period have approximately the same playback duration.

11. The system of claim 9, wherein the movie has a playback duration, the first period and the second period having a duration that is approximately half the playback duration.

12. An apparatus for streaming a movie on demand comprising:

a network interface;

a control system coupled to the network interface and configured to:

(i) send a request for the movie to a server, the movie having a plurality of portions that are encoded into a plurality of encoded portions, each encoded portion having a plurality of sections, wherein each segment of a plurality of segments comprises a section of some of the plurality of encoded portions, and wherein the plurality of portions corresponds to a time slice of the movie, and wherein the number of the plurality of portions of the time slice is approximately equal to a ratio of a predetermined download bandwidth to a predetermined upload bandwidth,

(ii) communicate with one or more nodes of a plurality of nodes distributed among a network, the one or more nodes being identified by the server in response to the request for the movie, and

(iii) receive a subset of the plurality of segments from the one or more nodes;

a decoder coupled to the network interface and configured to decode a subset of the plurality of sections so that less than all of the plurality of sections are used to play back the portions of the movie;

a video interface coupled to the decoder and configured to transmit the plurality of portions to a display device for play back;

wherein the apparatus enables (i) the movie to be played back in its entirety, and (ii) each portion of the movie to be played back in its entirety, without using all of the plurality of sections of that portion.

13. The apparatus of claim 12, further comprising a memory configured to store a second plurality of segments corresponding to a plurality of movies, and wherein the control system is further configured to transfer one of the second plurality of segments through the network interface in response to a network request.

14. The apparatus of claim 12, wherein the movie is encoded using an erasure code.

15. The apparatus of claim 12, wherein each section from the subset of the plurality of sections is from a respective segment from the subset of the plurality of segments.

16. The apparatus of claim 12, wherein at least two sections of the subset of the plurality of sections are from different subsets of the plurality of segments.

17. The apparatus of claim 12, wherein the plurality of portions of the movie comprise a first plurality of portions corresponding to a first period of the movie and a second plurality of portions corresponding to a second period of the movie, and wherein the plurality of encoded portions comprises a first plurality of encoded portions corresponding to the first period of the movie and a second plurality of encoded portions corresponding to the second period of the movie.

18. The apparatus of claim 17, wherein the subset of the plurality of segments comprises a plurality of primary segments and a backup segment, all the plurality of sections corresponding to the first period being from the plurality of primary segments and at least one of the plurality of sections corresponding to the second period being from the backup segment.

* * * * *