

PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

Express Mail Label No. EV 194331942 US

INVENTOR(S)					
Given Name (first and middle [if any])		Family Name or Surname		Residence (City and either State or Foreign Country)	
Nicholas		Millington		Santa Barbara, CA	
Additional inventors are being named on the _____ separately numbered sheets attached hereto					
TITLE OF THE INVENTION (500 characters max)					
Method for Synchronizing Audio Playback Between Multiple Networked Devices					
Direct all correspondence to: CORRESPONDENCE ADDRESS					
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ENCLOSED APPLICATION PARTS (check all that apply)					
☒ Specification Number of Pages 11					
☐ CD(s), Number _____					
☒ Drawing(s) Number of Sheets 2					
☐ Other (specify) _____					
☐ Application Date Sheet. See 37 CFR 1.76					
METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT					
☐ Applicant claims small entity status. See 37 CFR 1.27.					
☒ A check or money order is enclosed to cover the filing fees.					
☒ The Director is hereby authorized to charge filing fees or credit any overpayment to Deposit Account Number: 06-0600					
☐ Payment by credit card. Form PTO-2038 is attached.					
FILING FEE Amount (\$) \$160.00					
The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.					
☒ No.					
☐ Yes, the name of the U.S. Government agency and the Government contract number are: _____					

[Page 1 of 2]

Respectfully submitted,

SIGNATURE

TYPED or PRINTED NAME John S. Ferrell

TELEPHONE 650-812-3408

Date

07/28/2003

REGISTRATION NO.

34,593

(if appropriate)

Docket Number:

PA2593PRV

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

This collection of information is required by 37 CFR 1.51. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 8 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Mail Stop Provisional Application, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

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FEE TRANSMITTAL for FY 2003

Effective 01/01/2003. Patent fees are subject to annual revision.

☐ Applicant claims small entity status. See 37 CFR 1.27

TOTAL AMOUNT OF PAYMENT (\$) 200.00

Complete if Known

Application Number	Unknown
Filing Date	July 28, 2003
First Named Inventor	Nicholas Millington
Examiner Name	Unknown
Art Unit	Unknown
Attorney Docket No.	PA2593PRV

METHOD OF PAYMENT (check all that apply)

☒ Check ☐ Credit card ☐ Money Order ☐ Other ☐ None

☒ Deposit Account:

Deposit Account Number: 06-0600
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The Director is authorized to: (check all that apply)

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FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code (\$)	Small Entity Fee Code (\$)	Fee Description	Fee Paid
1001 750	2001 375	Utility filing fee	
1002 330	2002 165	Design filing fee	
1003 520	2003 260	Plant filing fee	
1004 750	2004 375	Reissue filing fee	
1005 160	2005 80	Provisional filing fee	160
SUBTOTAL (1)			(\$) 160.00

2. EXTRA CLAIM FEES FOR UTILITY AND REISSUE

Total Claims: 20 = x =
Independent Claims: 3 = x =
Multiple Dependent: x =

Large Entity Fee Code (\$)	Small Entity Fee Code (\$)	Fee Description	Fee Paid
1202 18	2202 9	Claims in excess of 20	
1201 84	2201 42	Independent claims in excess of 3	
1203 280	2203 140	Multiple dependent claim, if not paid	
1204 84	2204 42	** Reissue independent claims over original patent	
1205 18	2205 9	** Reissue claims in excess of 20 and over original patent	
SUBTOTAL (2)			(\$) 0

**or number previously paid, if greater. For Reissues, see above

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code (\$)	Small Entity Fee Code (\$)	Fee Description	Fee Paid
1051 130	2051 65	Surcharge - late filing fee or oath	
1052 50	2052 25	Surcharge - late provisional filing fee or cover sheet	
1053 130	1053 130	Non-English specification	
1812 2,520	1812 2,520	For filing a request for <i>ex parte</i> reexamination	
1804 920*	1804 920*	Requesting publication of SIR prior to Examiner action	
1805 1,840*	1805 1,840*	Requesting publication of SIR after Examiner action	
1251 110	2251 55	Extension for reply within first month	
1252 410	2252 205	Extension for reply within second month	
1253 930	2253 465	Extension for reply within third month	
1254 1,450	2254 725	Extension for reply within fourth month	
1255 1,970	2255 985	Extension for reply within fifth month	
1401 320	2401 160	Notice of Appeal	
1402 320	2402 160	Filing a brief in support of an appeal	
1403 280	2403 140	Request for oral hearing	
1451 1,510	1451 1,510	Petition to institute a public use proceeding	
1452 110	2452 55	Petition to revive - unavoidable	
1453 1,300	2453 650	Petition to revive - unintentional	
1501 1,300	2501 650	Utility issue fee (or reissue)	
1502 470	2502 235	Design issue fee	
1503 630	2503 315	Plant issue fee	
1460 130	1460 130	Petitions to the Commissioner	
1807 50	1807 50	Processing fee under 37 CFR 1.17(q)	
1806 180	1806 180	Submission of Information Disclosure Stmt	
8021 40	8021 40	Recording each patent assignment per property (times number of properties)	40
1809 750	2809 375	Filing a submission after final rejection (37 CFR 1.129(a))	
1810 750	2810 375	For each additional invention to be examined (37 CFR 1.129(b))	
1801 750	2801 375	Request for Continued Examination (RCE)	
1802 900	1802 900	Request for expedited examination of a design application	

Other fee (specify):

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SUBTOTAL (3) (\$) 40.00

SUBMITTED BY

Name (Print/Type)	John S. Ferrell	Registration No. (Attorney/Agent)	34,593	Telephone	650-812-3408
Signature		Date	July 28, 2003		

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METHOD FOR SYNCHRONIZING AUDIO PLAYBACK BETWEEN MULTIPLE NETWORKED DEVICES

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention generally relates to synchronizing audio playback between two or more networked devices. More particularly, the present invention provides an algorithm to synchronize audio playback among multiple networked devices when exact timing information is not known.

Description of the Background Art

[0002] The essential problem in multi-zone audio playback is to pair a media source with one or more media players, and have the latter render the audio in time synchronization with one another. This requires devices to have knowledge of other components on the network, a means to communicate with them, and certain timing information.

[0003] Discovery protocols can be used to learn about other components on the network and to establish communication with them. For example, the Universal Plug and Play (UPnP) architecture defines discovery as the first step in UPnP networking. This allows devices to discover other devices and to exchange information about themselves and/or their services.

[0004] Timing information can be distributed to various network connected devices using network time protocols such as Network Time Protocol (NTP) and Simple Network Time Protocol (SNTP). These protocols, however, only provide a distribution

mechanism for timing information; they do not provide the algorithms to synchronize playback using such timing information.

BRIEF DESCRIPTION OF THE FIGURES

[0005] FIG. 1 shows an exemplary networked audio system consisting of three networked devices and a common media source;

[0006] FIG. 2 shows an exemplary set of the digital audio portion of MP3 frames highlighting the back-pointer function, where data for one frame are included in previous frames;

[0007] FIG. 3 shows an exemplary system where digital audio MP3 frames are processed in a DAC at times t_0 , t_0+n/v , t_0+2n/v , ...;

[0008] FIG. 4 shows an exemplary system for synchronized playback between the master and slave players.

DESCRIPTION OF PREFERRED EMBODIMENTS

[0009] An exemplary embodiment of a network audio system consists of two or more networked devices capable of playing the same audio signal from a common media source. At times, these devices may need to agree when an operation is to take place. One example would be live audio playback: if a live audio stream needs to be played simultaneously by two devices that have different network latencies between themselves and the media source, they must coordinate to establish the delay that needs to be introduced on one (or both) of the players to compensate for the different network latency.

[00010] The present invention does not assume synchronization is maintained when devices are playing different audio signals or when they are not currently playing audio signals.

[00011] The present invention utilizes control messages that are exchanged by the networked devices to coordinate audio playback. These messages include a time component specifying when the operation is to take place. The time component is used to coordinate the execution of the operation in time synchronization with multiple devices, even though they may receive the control signal serially (e.g., due to the serial nature of unicast communication over a shared medium). The time component included in the control message uses the local time of the device originating the control message. The time may be converted to the local time of the receiving device using an estimate of clock skew between the devices.

[00012] The synchronization algorithm follows a master/slave model whereby one device (master) provides timing information to the other devices (slaves) playing the

same audio file. The simple network time protocol (SNTP) is an exemplary embodiment of a protocol to provide timing information to networked devices. The timing information can then be used to obtain an understanding of the difference between the slaves' local clocks and that of the master clock at any given time.

[00013] Digital audio being played has a sampling frequency, v , which determines the ideal number of samples to be consumed per second.

[00014] For encoding and decoding purposes, a digital audio file can also be divided into frames that consist of a certain number of samples, n . For example, in the MPEG Audio Layer-3 (MP3) format each frame holds 1152 samples of audio. Since the length in samples of the frame is fixed, the amount of digital audio data in a frame can vary as a function of sample frequency, sample resolution, specified bitrate, etc. In addition, frames are not entirely independent of one another. In the MP3 format, for example, each audio frame contains a field called `main_data_begin` that is a back-pointer to a location in one of the eight audio frames prior to the current one. This complicates the process of seeking within the file.

[00015] Audio playback begins on the master player at time t_0 according to that player's local clock. As the master player plays its samples, it will receive frames of audio beginning at sample 0, n , $2n$, $3n$, $4n$, etc. During the playback of a particular frame, it is possible to estimate when, in terms of the master player's local clock, the first sample in that frame of audio will be played back on the master player's digital-analog converter (DAC) by taking the instantaneous value of the number of samples that an audio driver controlling the DAC has buffered, dividing this value by the sample

frequency, and adding the resulting number of seconds (or more likely fractions of a second) to the current time on the master player's system clock.

[00016] If playback of the first frame begins at time t_0 , there are also "ideal" times (with respect to the master player's local clock) for the subsequent frames to play. These are given by $t_0 + n/v$, $t_0 + 2n/v$, $t_0 + 3n/v$, etc. The observed frame start time may be made to approach the ideal start time by adjusting the clock speed of the DAC. If the observed times are before the ideal times, the DAC clock is slowed down, while if the observed times are after the ideal times, the DAC clock is sped up. Therefore, while this algorithm is running on the master player, it is possible for an observer with knowledge of the master player's start time (or any absolute time) and sample rate of the digital audio being played to have highly accurate knowledge of what sample within a given digital audio file is currently playing.

[00017] A "slave" player is a player that is attempting to synchronize with a master player. The slave player also has a local clock, and it runs a network timing protocol to obtain information about the master clock. One embodiment is for the slave player to run an SNTP client thread. The SNTP client thread regularly queries the SNTP server process on the master player, so that knowledge of the current difference between the two clocks is maintained.

[00018] When synchronized playback is to begin, the slave obtains a "status report" from the master. The status report includes the master's location within the current digital audio file and the *ideal time* with respect to the *master clock* when the frame at that location within the file should play. The slave player then runs the same algorithm as the master: from its starting point it may calculate ideal times (with respect

to the master clock) when subsequent frames of audio should play. It may then compare those ideal times to the observed times and adjust its DAC speed up or down to force them to converge. In one embodiment, observed times on the slave, which would naturally be measured with respect to its local clock, are converted to master clock times, for comparison to the ideal times. This conversion is performed using the clock difference between the master and slave that is obtained through the network time protocol (e.g., SNTP). Thus, the slave's audio playback is synchronized to the master's clock instead of its own, as desired.

Playlist Playback

[00019] A playlist is an ordered list of digital audio files. The format with which the files are addressed and the mechanism for storing playlists are well known in the art. One embodiment of the present invention synchronizes playback of a playlist. The following is an exemplary embodiment of synchronizing playback of a playlist.

Startup

[00020] Once a playlist has been obtained by a player, it can be played in synchronization with other players at a scheduled time in the future. The coordination may be performed by the master player by scheduling the playback at a future time and communicating this future time to all the slave players.

[00021] In order to support 'joining' the playback of an existing playlist, a player should be able to report its precise location, both within the playlist and within a particular song. An exemplary body of such a report will look something like this:

[00022] At time a according to my local clock I sent the first sample that resulted from decoding the frame that began at offset b in file c on my playlist to the DAC. The

earliest frame of 'prior knowledge' needed to decode this frame began at offset d in the file.

[00023] Since the DAC consumes samples at a constant rate (e.g. 44.1 k-samples per second), it is a natural point at which to implement the synchronization. With this information, the synchronization algorithm is as follows:

[00024] 1. Open the audio file c .

[00025] 2. Seek to location d , and begin reading the file.

[00026] 3. Once the frame at offset b is encountered, start decoding. Assign a timestamp to each decoded frame, where the first frame has timestamp a , the second frame has timestamp $a + v/n$ ms, etc., where v is the sampling frequency and n is the number of samples per frame.

[00027] 4. At some point, a frame will be decoded whose timestamp is greater than the current time on the synchronizing player. At this point, wait for the current time to catch up with the timestamp, and start outputting audio to the DAC. At this point, synchronization has been achieved.

[00028] The algorithm assumes either it is possible to decode audio at a rate faster than it is being consumed by the DAC or that it is possible to skip frames without actually decoding the audio.

[00029] In one embodiment, to avoid synchronization problems associated with joining a playlist as a particular track is ending; each player maintains a copy of the playlist. The silence intervals between tracks can also run through the same synchronization algorithms.

Navigation within a playlist

[00030] In another embodiment, a playlist feature that can be supported using the synchronization algorithm discussed above is the forward/backward navigation within a playlist while the playlist is being played on multiple audio players. This can be accomplished, for example, by scheduling the track navigation for some later moment, and have the players perform the navigation in sync at that point. The moment in the future at which the navigation is to occur can be chosen. In order for the UI to appear responsive to the user, the delay should be as short as possible, but it must be long enough to allow all players to receive the control signal and buffer data for the next/previous track. Several factors such as network latency, congestion, number of players participating in the playback (in the case of unicast communication over a shared medium), etc. can be used to assist with picking this time.

What is Claimed:

- 1 1. An audio synchronization scheme comprising:
2 a plurality of networked devices configured to synchronize audio
3 playback when exact timing information is not known.
- 1 2. The system of claim 1 wherein a control message is exchanged between
2 network devices to coordinate audio playback.
- 1 3. The system of claim 2 wherein the control message contains a time
2 component and a frame identifier specifying when the synchronized
3 operation is to take place.
- 1 4. The system of claim 3 wherein the time component is the local time of the
2 device originating the control message.
- 1 5. The system of claim 4 wherein networked devices can join the system
2 during playback in audio synchronization
- 1 6. The system of claim 4 wherein synchronized playback of a playlist occurs.

- 1 7. The system of claim 6 wherein joining the playback of an existing playlist
- 2 occurs in a synchronized fashion.

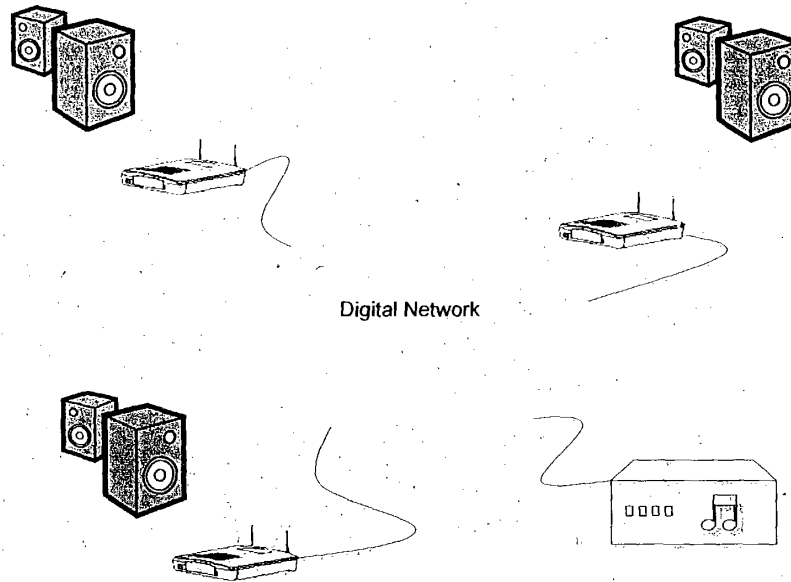


FIG 1.

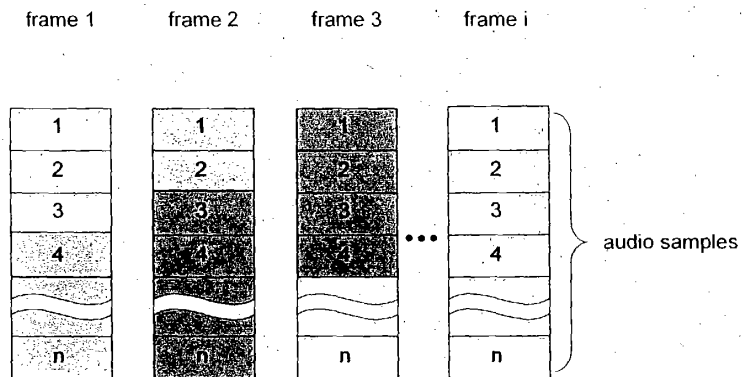


FIG 2.

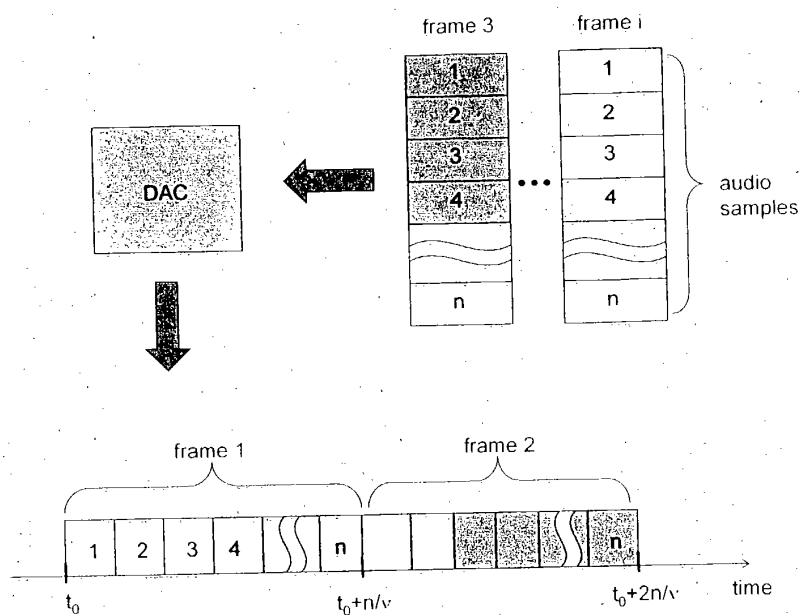


FIG. 3

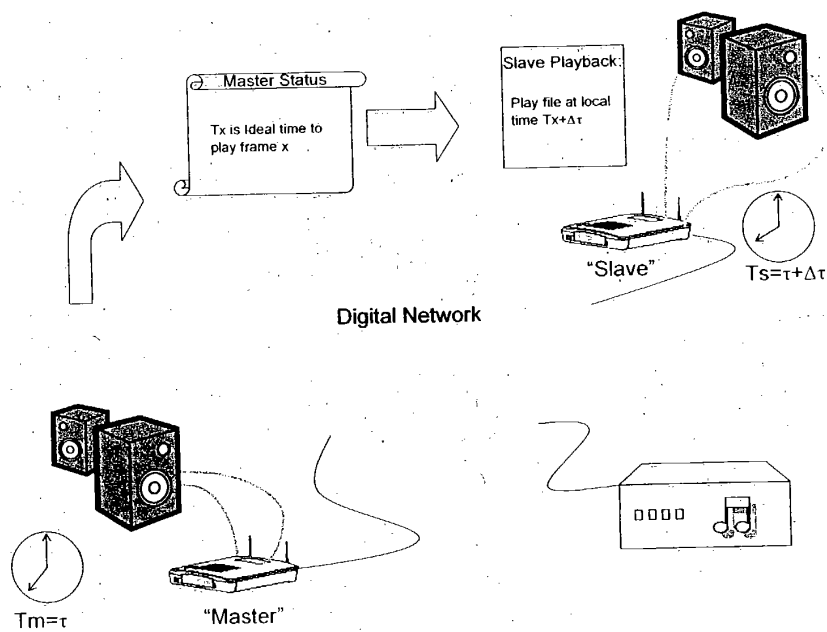


FIG. 4

PATENT APPLICATION SERIAL NO. _____

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE
FEE RECORD SHEET

07/31/2003 ZJUHA1 00000062 60490768

01 FC:1005 160.00 DP

PTO-1556
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*U.S. Government Printing Office: 2002 — 489-267/69033

ARTIFACT SHEET

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60490768 C.A

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☐

Model(s)

Doc Code: Artifact

Artifact Type Code: M

☐

Bound Document(s)

Doc Code: Artifact

Artifact Type Code: B

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Other, description: _____

Doc Code: Artifact

Artifact Type Code: Z

06/26/2003