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Kuhn

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(54) **DYNAMIC AND AUTOMATIC CONTROL OF LATENCY BUFFERING FOR AUDIO/VIDEO STREAMING**

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H04N 21/24	(2011.01)
H04N 21/242	(2011.01)

(Continued)

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CPC ***H04L 65/607*** (2013.01); ***H04N 21/23406*** (2013.01); ***H04N 21/2401*** (2013.01); ***H04N 21/2402*** (2013.01); ***H04N 21/242*** (2013.01); ***H04N 21/44004*** (2013.01); *H04N 21/2389* (2013.01)

(58) **Field of Classification Search**

CPC H04L 65/607; H04L 47/30; H04W 40/00; H04W 36/02; H04W 28/14; H04W 36/023; H04W 72/1221; H04W 72/1284; H04W 36/00; G11B 20/12; G11B 20/18; G11B 20/10527; G11B 19/044; G11B 20/00; G11B 27/00; G11B 20/10; G06F 3/0656; G06F 3/06; H04N 21/44004; H04N 21/242; H04N 21/2402; H04N 21/23406; H04N 21/2401; H04N 21/2389

USPC 709/231

See application file for complete search history.

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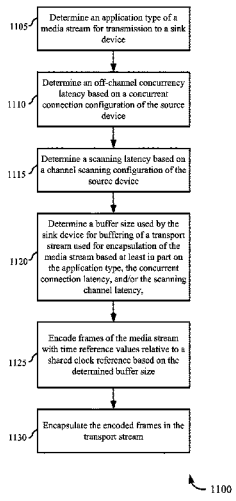
(57) **ABSTRACT**

Dynamic control by a source device of sink buffer size for audio and/or video streaming over an error-prone channel. The sink buffer size may be determined based on a type of application for a media stream being transmitted from the source device to the sink device for presentation. The techniques may select a buffer size that is smaller for gaming applications, larger for interactive media applications, and even larger for non-interactive media types. The techniques adjust the time delta between a shared clock reference and time reference values of a transport stream that are used by the sink device to determine decoding or presenting of media frames of the transport stream relative to a shared clock reference. In addition, the techniques may account for transceiver latency at the source device due to scanning or multiple concurrent connections.

48 Claims, 11 Drawing Sheets



(51) **Int. Cl.**
H04N 21/44 (2011.01)
H04N 21/2389 (2011.01)

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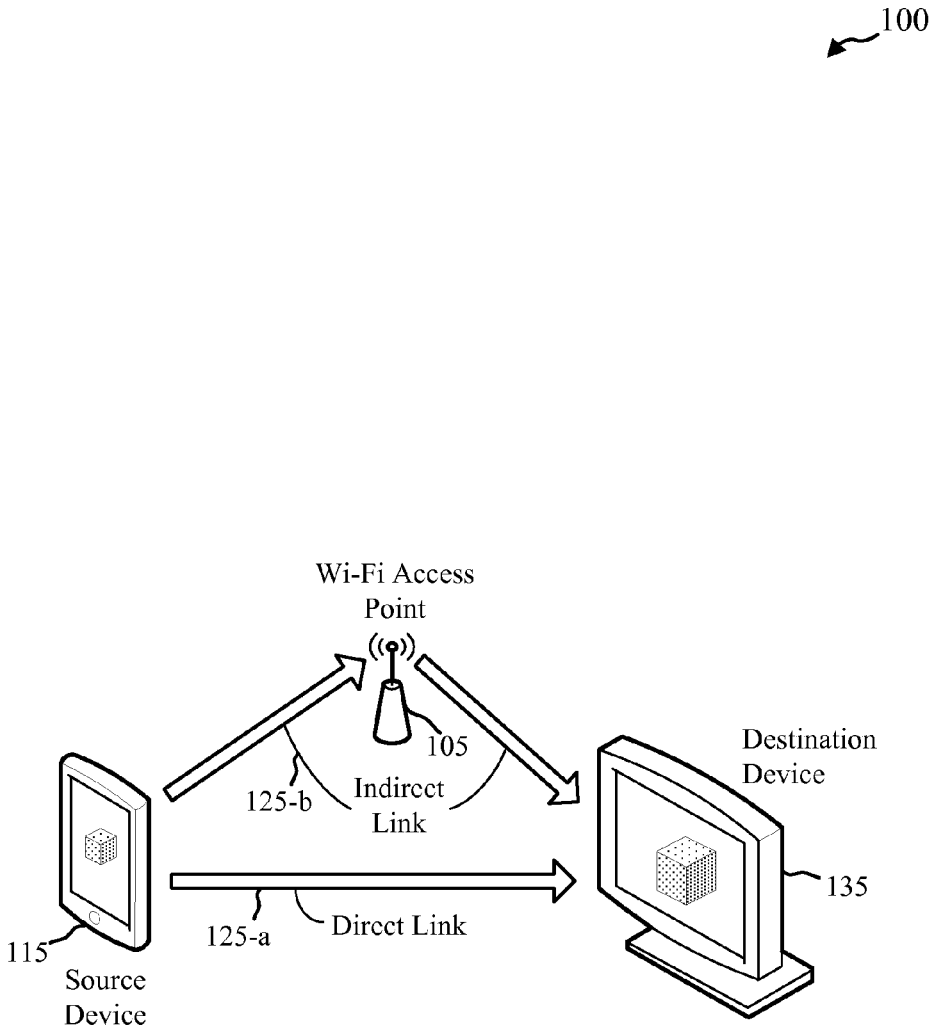
100
Wi-Fi Access Point
105
Destination Device
125-b
Indirect Link
135
125-a
Direct Link
115
Source Device

FIG. 1

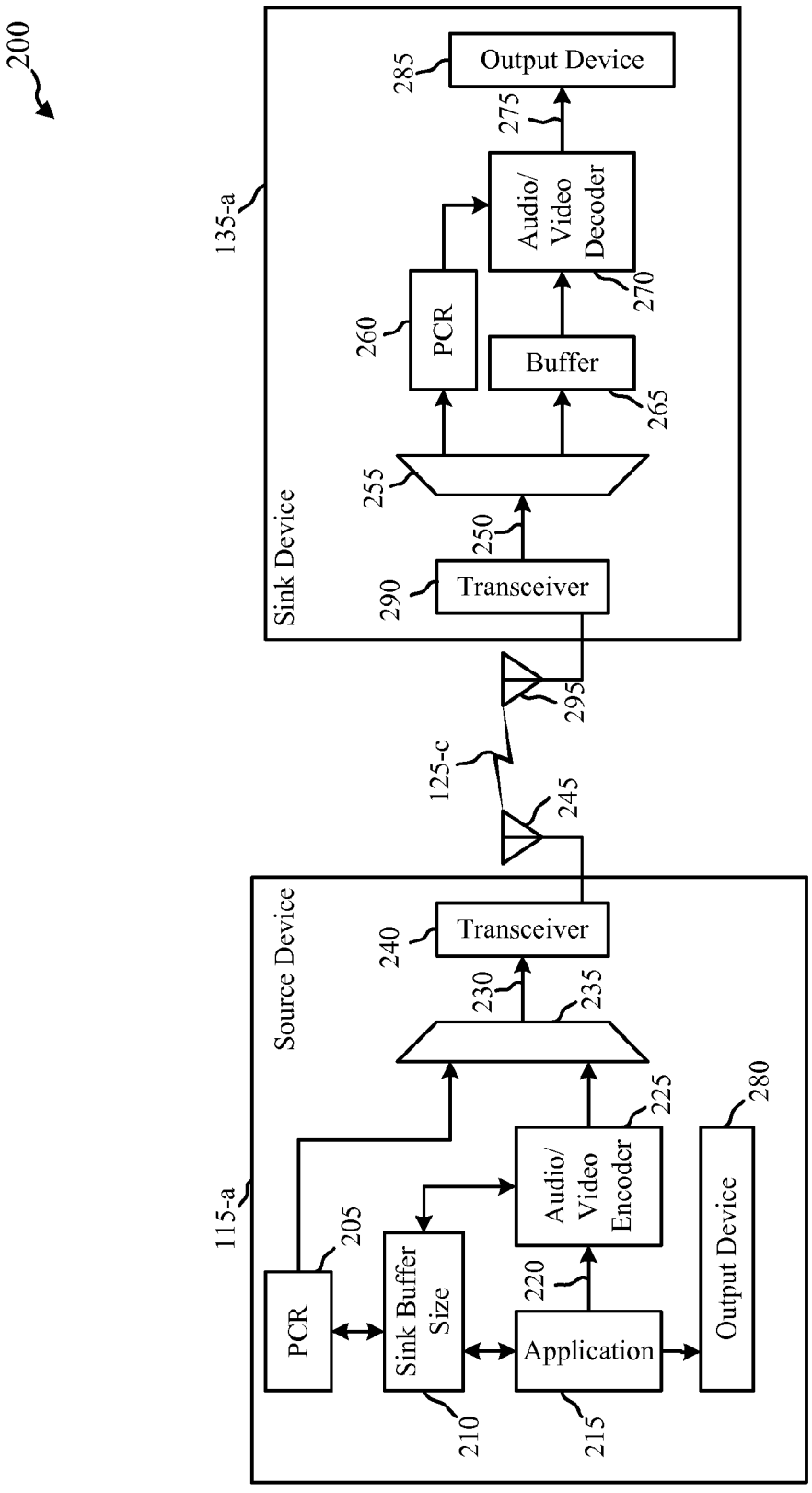
200
115-a
Source Device
PCR
205
Sink Buffer Size
210
Application
215
220
Audio/ Video Encoder
225
Output Device
280
Transceiver
240
230
235
125-c
245
295
135-a
Sink Device
Transceiver
290
250
255
PCR
260
Buffer
265
Audio/ Video Decoder
270
275
Output Device
285

FIG. 2

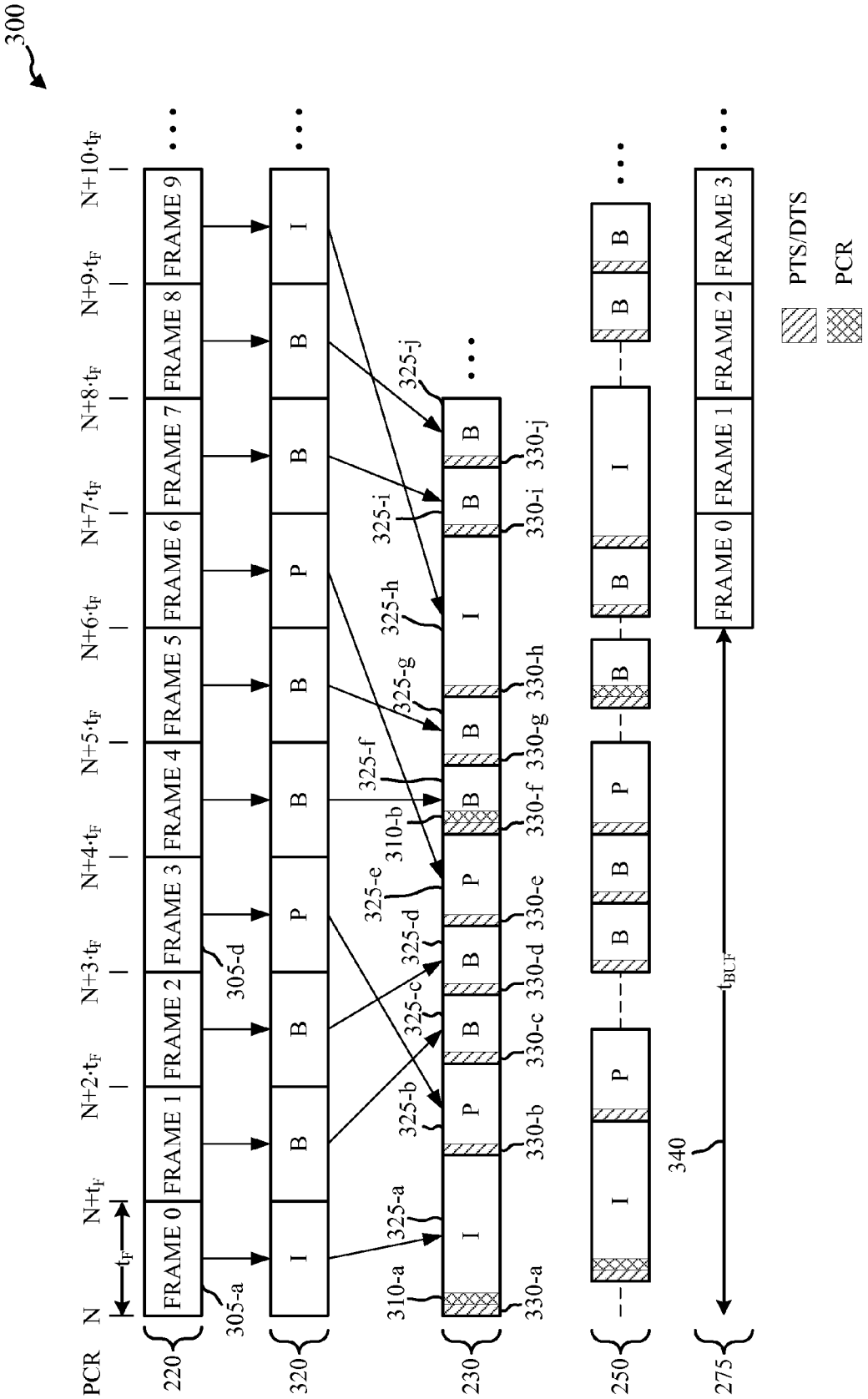
300
PCR
N
N+t_F
N+2·t_F
N+3·t_F
N+4·t_F
N+5·t_F
N+6·t_F
N+7·t_F
N+8·t_F
N+9·t_F
N+10·t_F
t_F
FRAME 0
FRAME 1
FRAME 2
FRAME 3
FRAME 4
FRAME 5
FRAME 6
FRAME 7
FRAME 8
FRAME 9
220
320
230
250
275
305-a
305-d
310-a
310-b
325-a
325-b
325-c
325-d
325-e
325-f
325-g
325-h
325-i
325-j
330-a
330-b
330-c
330-d
330-e
330-f
330-g
330-h
330-i
330-j
340
t_BUF
I
B
P
PTS/DTS
PCR

FIG. 3

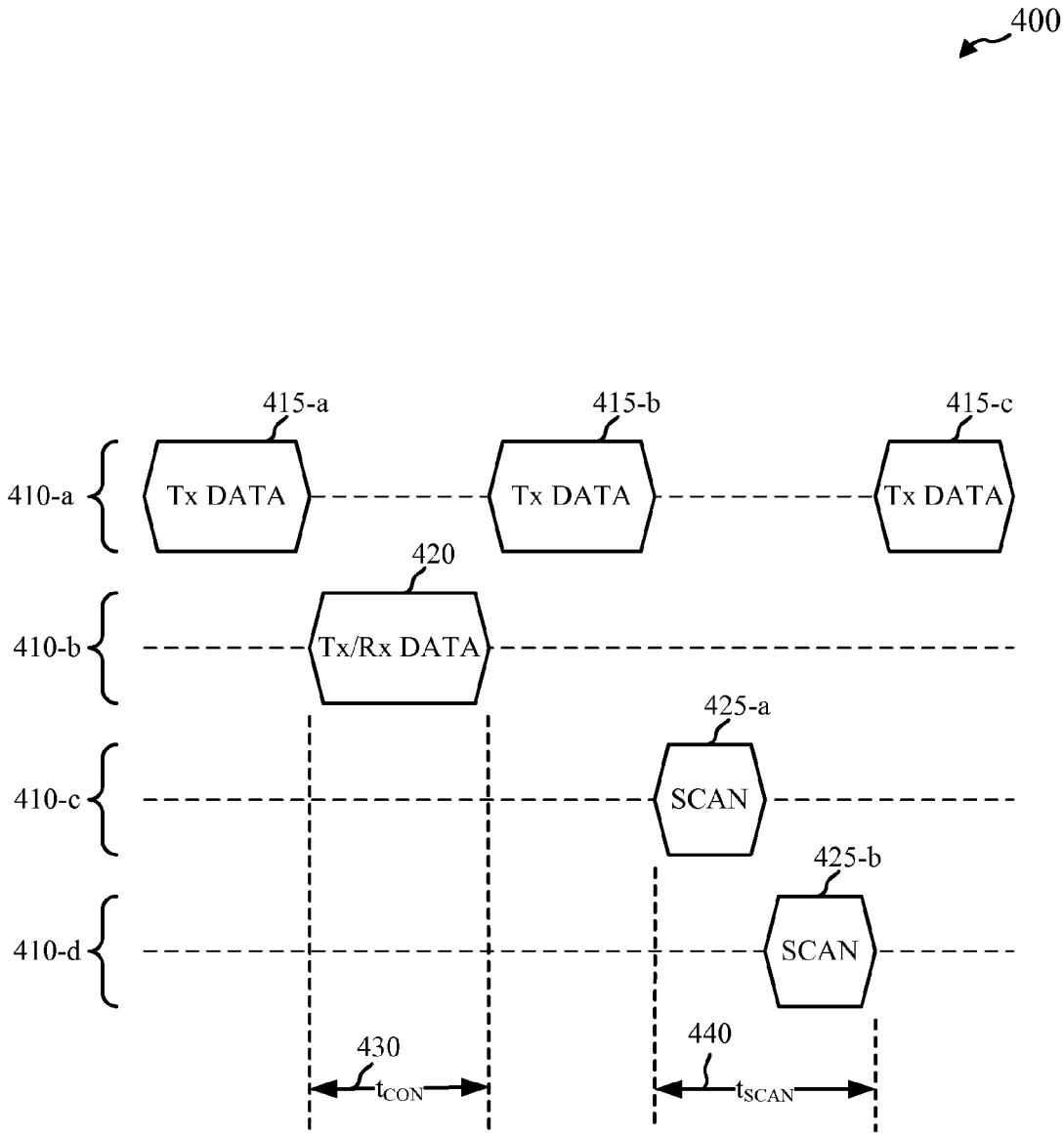
400
415-a
415-b
415-c
410-a
Tx DATA
Tx DATA
Tx DATA
420
410-b
Tx/Rx DATA
425-a
410-c
SCAN
425-b
410-d
SCAN
430
t_{CON}
440
t_{SCAN}

FIG. 4

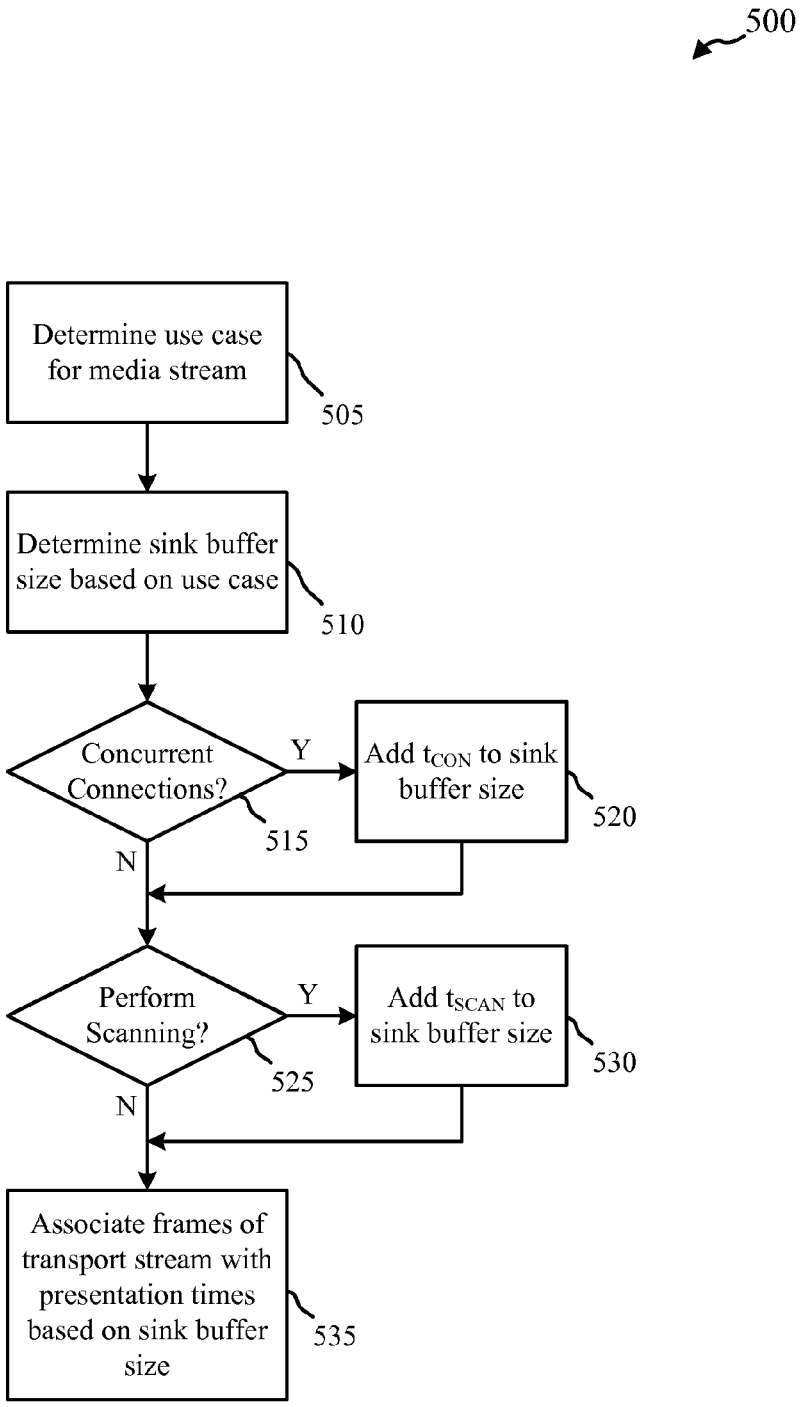
500
Determine use case for media stream
505
Determine sink buffer size based on use case
510
Concurrent Connections?
515
Y
N
Add t_{CON} to sink buffer size
520
Perform Scanning?
525
Y
N
Add t_{SCAN} to sink buffer size
530
Associate frames of transport stream with presentation times based on sink buffer size
535

FIG. 5

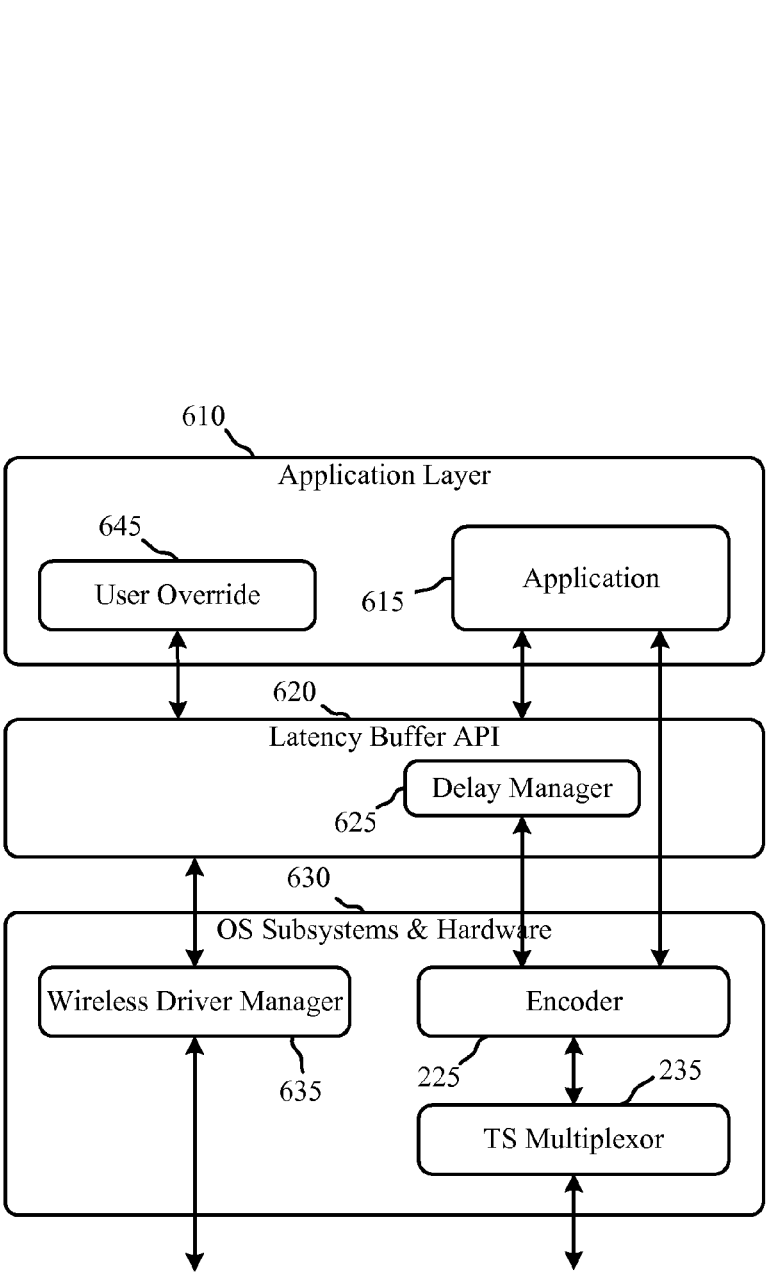
600
610
Application Layer
645
User Override
615
Application
620
Latency Buffer API
Delay Manager
625
630
OS Subsystems & Hardware
Wireless Driver Manager
635
Encoder
225
235
TS Multiplexor

FIG. 6

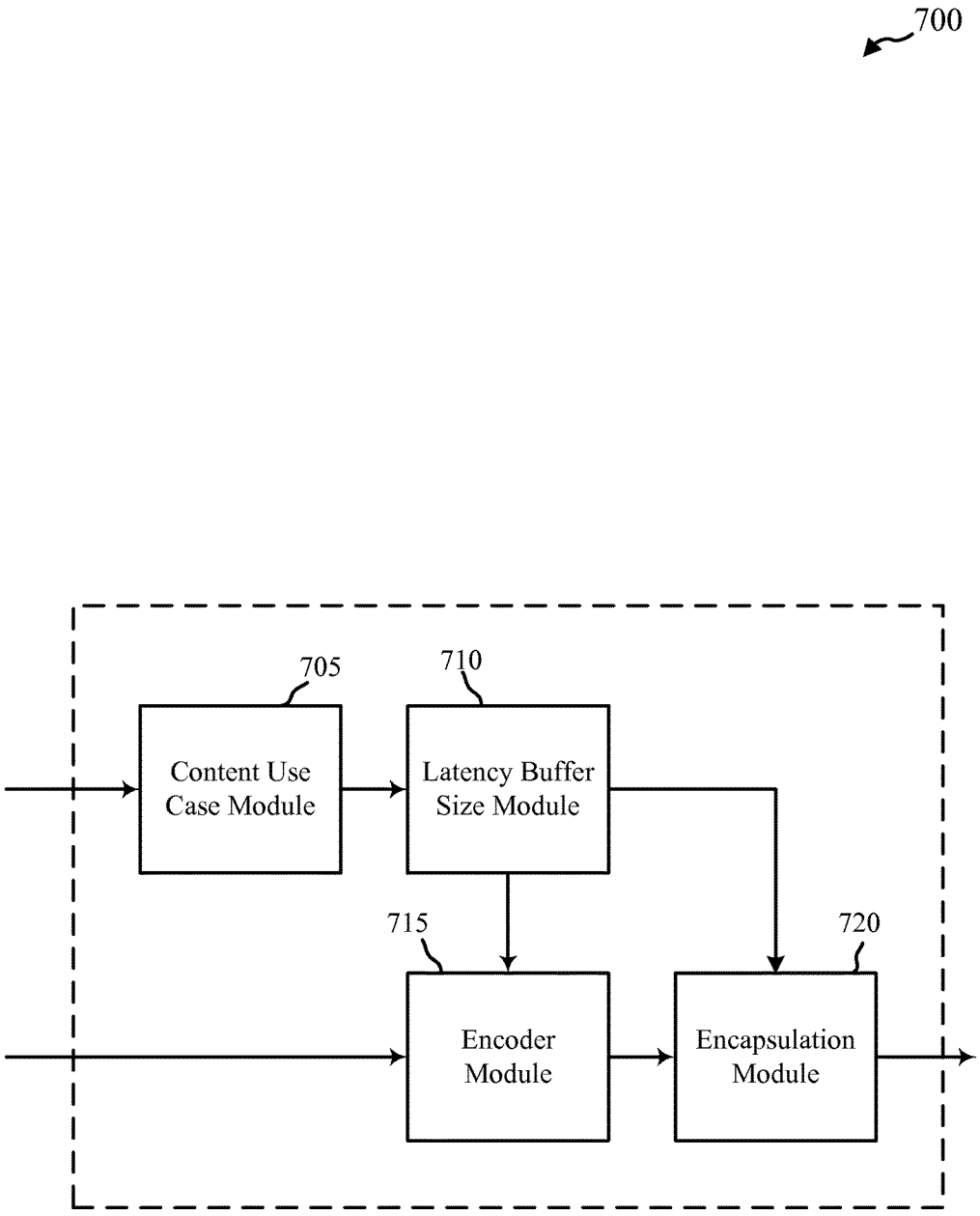
700
705
710
Content Use Case Module
Latency Buffer Size Module
715
720
Encoder Module
Encapsulation Module

FIG. 7

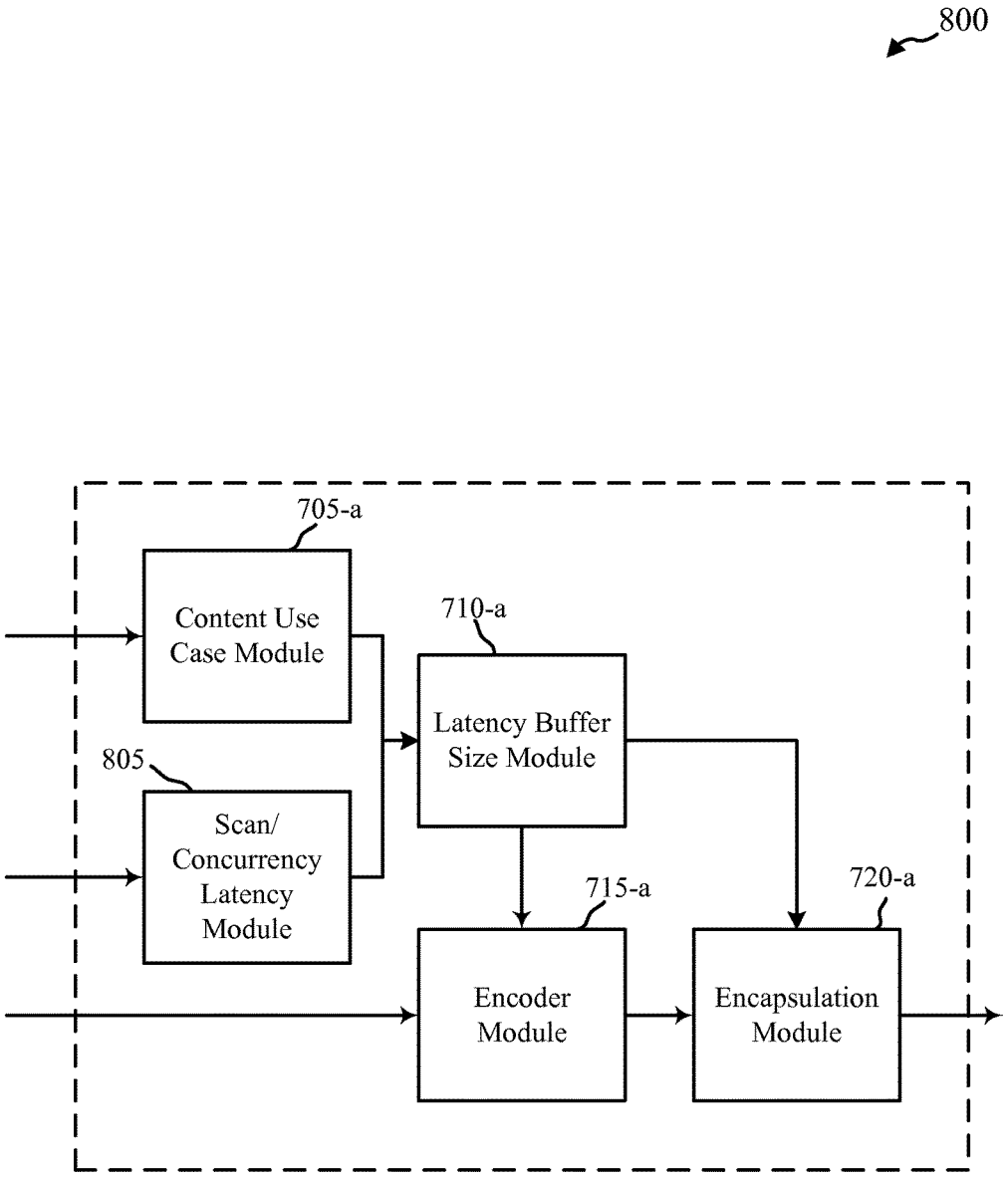
800
705-a
Content Use Case Module
710-a
Latency Buffer Size Module
805
Scan/ Concurrency Latency Module
715-a
720-a
Encoder Module
Encapsulation Module

FIG. 8

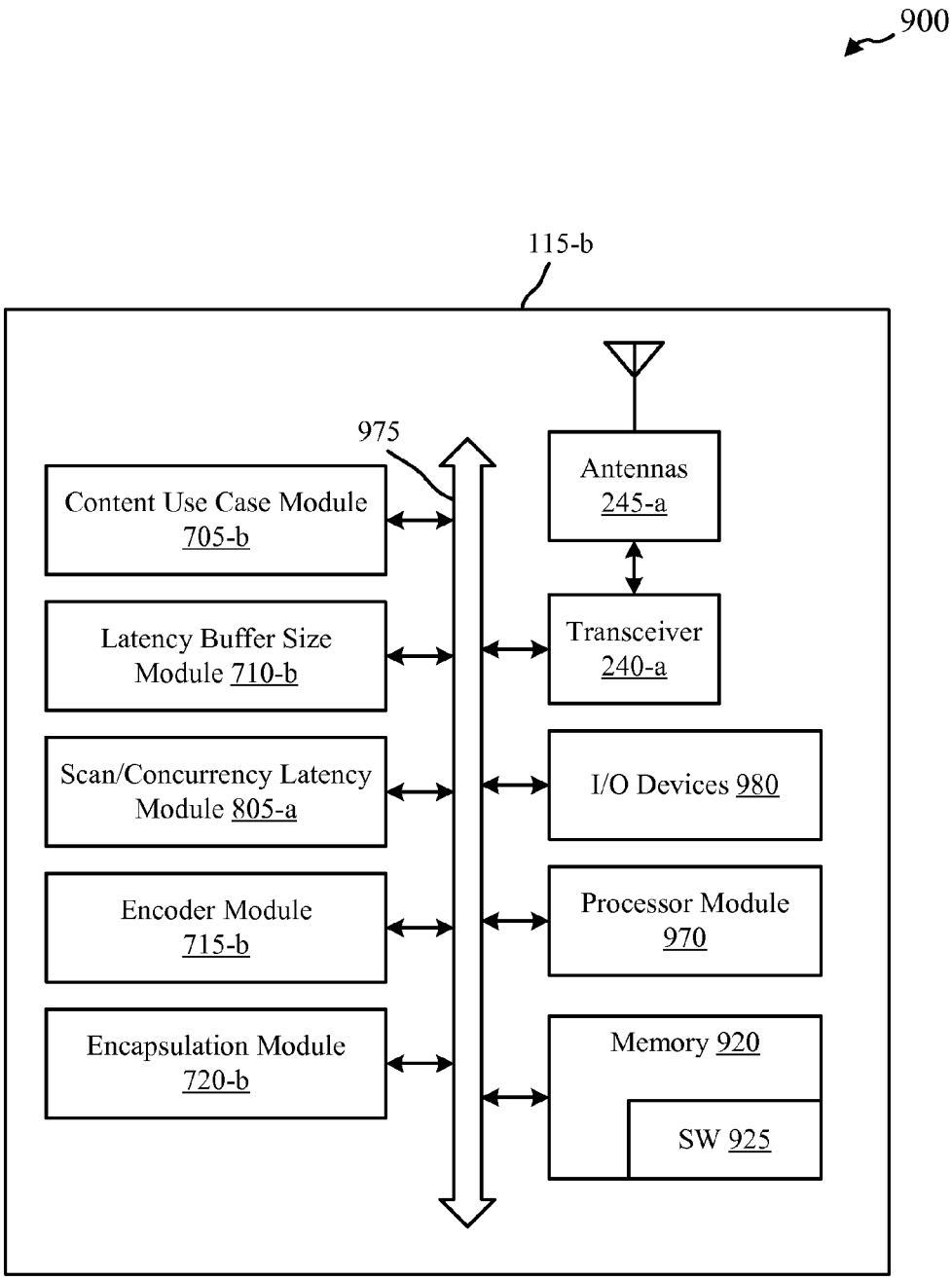
900
115-b
975
Content Use Case Module 705-b
Latency Buffer Size Module 710-b
Scan/Concurrency Latency Module 805-a
Encoder Module 715-b
Encapsulation Module 720-b
Antennas 245-a
Transceiver 240-a
I/O Devices 980
Processor Module 970
Memory 920
SW 925

FIG. 9

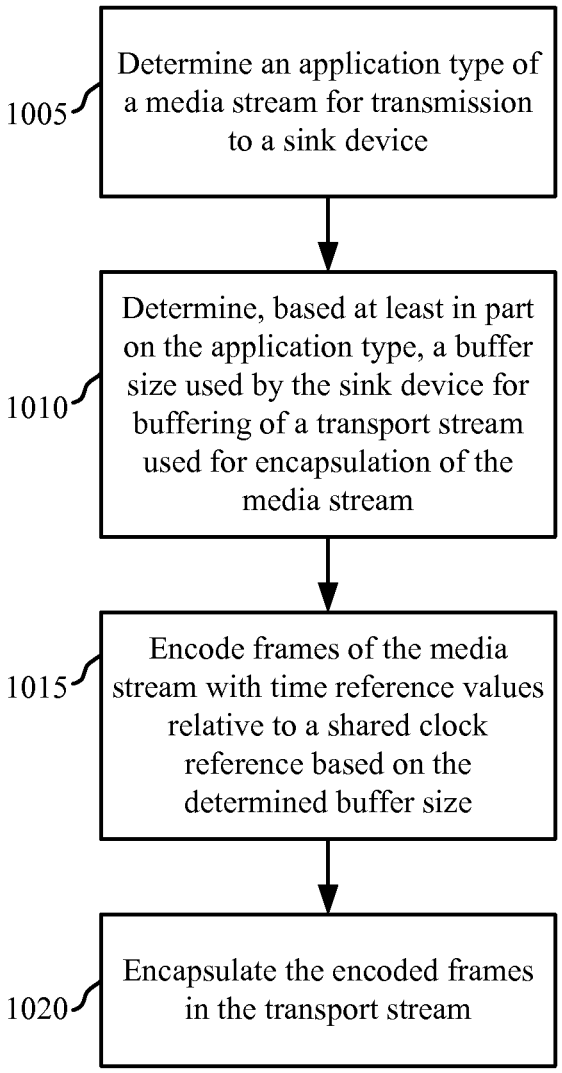
Determine an application type of a media stream for transmission to a sink device
1005
Determine, based at least in part on the application type, a buffer size used by the sink device for buffering of a transport stream used for encapsulation of the media stream
1010
Encode frames of the media stream with time reference values relative to a shared clock reference based on the determined buffer size
1015
Encapsulate the encoded frames in the transport stream
1020
1000

FIG. 10

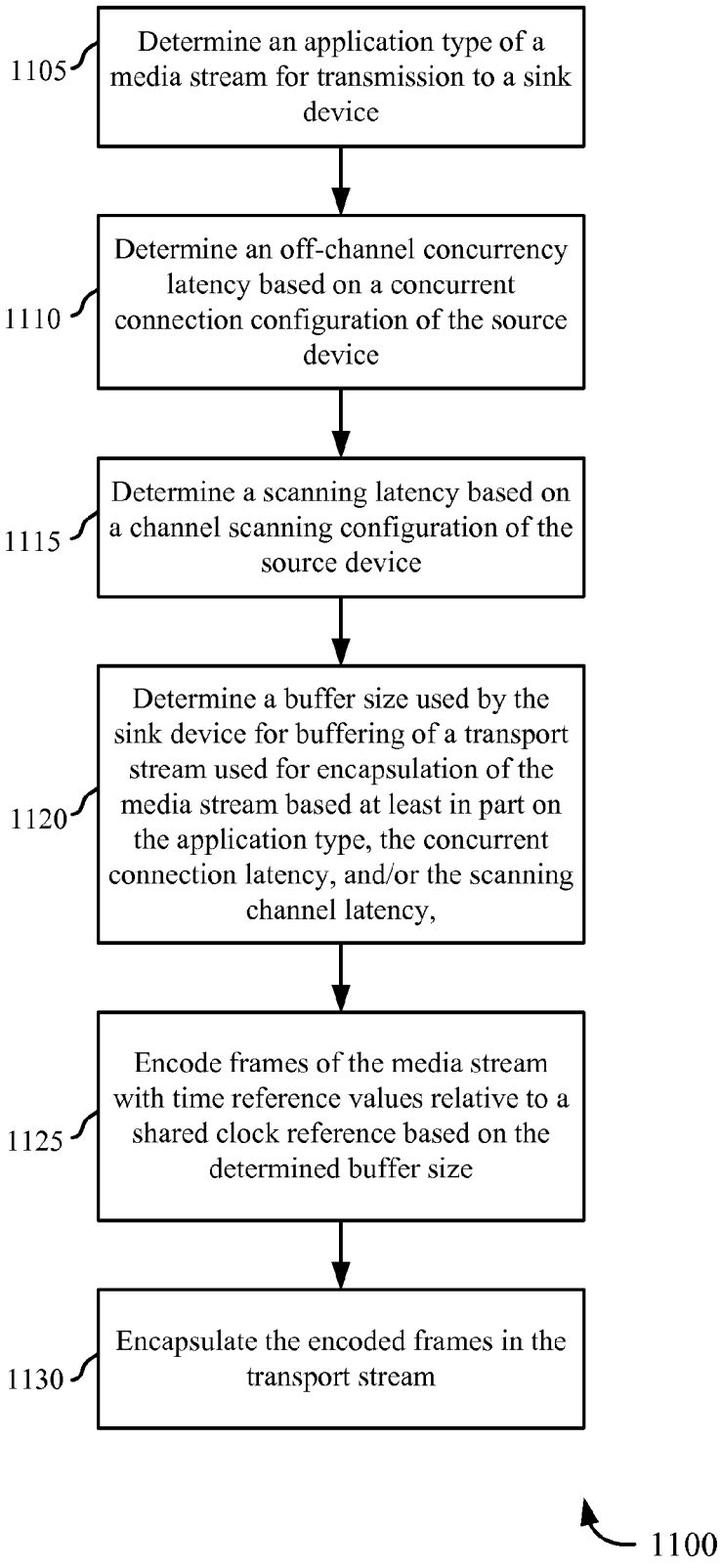
1105
Determine an application type of a media stream for transmission to a sink device
1110
Determine an off-channel concurrency latency based on a concurrent connection configuration of the source device
1115
Determine a scanning latency based on a channel scanning configuration of the source device
1120
Determine a buffer size used by the sink device for buffering of a transport stream used for encapsulation of the media stream based at least in part on the application type, the concurrent connection latency, and/or the scanning channel latency,
1125
Encode frames of the media stream with time reference values relative to a shared clock reference based on the determined buffer size
1130
Encapsulate the encoded frames in the transport stream
1100

FIG. 11

DYNAMIC AND AUTOMATIC CONTROL OF LATENCY BUFFERING FOR AUDIO/VIDEO STREAMING

BACKGROUND

The following relates generally to communications, and more specifically to transmission of media content for display on a sink display device. Wired and wireless communications systems are widely deployed to communicate various types of content such as voice, video, packet data, messaging, broadcast, and so on. Wired communication systems include packet-based communication systems (e.g., Ethernet, and the like) and non-packet based communication systems. Wireless communication systems include wireless local area network (WLAN), and cellular multiple-access systems. Generally, these wireless communication systems are capable of supporting communication with multiple users by sharing the available system resources (e.g., time, frequency, and power). Wireless communication systems may use radio technologies for multiple-access including code-division multiple access (CDMA), time-division multiple access (TDMA), frequency-division multiple access (FDMA), and orthogonal frequency-division multiple access (OFDMA). Some communication systems experience variability in latency between packets of information in a communication flow. Variation in latency may be caused by a variety of factors including traffic congestion, packet loss and retry, and the like.

As mobile devices become used more and more for capturing or generating content such as audio, video, or multimedia, users want to be able to share content between mobile devices and other devices such as TVs, computers, audio systems, and the like. One approach mirrors what is displayed on a source device (e.g., smartphone, tablet, and the like) with a sink device (e.g., TV, etc.). In some applications, the source device may transmit the media stream over a wireless link operating according to one of the 802.11 family of standards ("Wi-Fi"). Because Wi-Fi is often jittery and error-prone, some amount of buffering is provided at the sink device to smooth the jitter and packet latency caused by errors in the channel (e.g., retransmissions of data, etc.) to maintain good quality of video rendered at the sink device. It may also be desirable to reduce latency between capture or display of the video at the source device and display of the video at the sink device. However, reducing latency may conflict with maintaining good quality of video at the sink device.

SUMMARY

The described features generally relate to one or more improved systems, methods, and/or apparatuses for dynamic control of latency or jitter buffer size at the sink device for audio and/or video streaming over an error-prone channel. The sink buffer size may be dynamically controlled by the source device based on a type of application for a media stream being transmitted from the source device to the sink device for presentation. For example, the techniques may select a buffer size that is smaller for gaming applications, larger for interactive media applications (e.g., interactive computing, presentations, bi-directional communication, etc.), and even larger for non-interactive media types (e.g., streaming video, static images, etc.). The techniques adjust the time delta between a shared clock reference and time reference values of a transport stream that are used by the sink device to determine decoding or presenting of media frames of the transport stream relative to a shared clock reference.

In embodiments, the source device encapsulates content using an MPEG2 Transport Stream (MPEG-TS) for transmission over a medium. The source device may adjust the time delta between the program clock reference (PCR) and presentation time stamp (PTS) and/or decode time stamp (DTS) values in the MPEG-TS to control the amount of latency or jitter buffering at the sink device before decoding and rendering of the content stream. In addition, the techniques may account for transceiver latency at the source device due to scanning or multiple concurrent connections. While application-based sink buffer size control is described with reference to use of a transport stream over Wi-Fi, these techniques may be applied to encoded content transmitted in a transport stream over any wired or wireless transmission medium for which latency buffering may be applied.

In some embodiments, application-based sink buffer size control is implemented via an internal application programming interface (API) of the source device. The API may determine a use case or application type by program calls of the application or by monitoring a task manager and may determine an amount of buffering based on the application type. The API may determine concurrency and/or scanning operation of the source device based on parameters associated with communication drivers and may increase the amount of buffering based on the scanning or concurrency operation. The API may notify the encoder and transport stream multiplexor of the buffer time delta and the encoder and multiplexor may associate DTS and/or PTS values with audio and/or video frames of the encoded content in the transport stream according to the buffer time delta and PCR. In embodiments, a user override may be provided to allow explicit configuration of the buffer time delta.

Some embodiments are directed to a method performed by a source device, including determining an application type of a media stream for transmission to a sink device, determining, based at least in part on the application type, a buffer size used by the sink device for buffering of a transport stream used for encapsulation of the media stream, encoding frames of the media stream with time reference values relative to a shared clock reference based on the determined buffer size, and encapsulating the encoded frames in the transport stream.

Determining the application type may be based on an application associated with the media stream. For example, the application type of the media stream may be a gaming application type, an interactive computing application type, or a media viewing application type. The method may include receiving, by an application programming interface of the source device, a call from an application running on the source device for establishing a streaming display connection with the sink device. The application type of the media stream may be determined based on the received call.

In some embodiments the method includes determining an off-channel concurrency latency based on a concurrent connection configuration of the source device. Determining the buffer size may be further based on the off-channel concurrency latency. In some embodiments, the method includes determining a scanning latency is based on a channel scanning configuration of the source device. Determining the buffer size may be further based on the scanning latency.

In some embodiments, the method includes transmitting the transport stream to the sink device over a wireless local area network connection. The method may include display-

ing the media stream at the source device concurrently with encoding of the media stream for transmission to the sink device. The method may include transmitting time values of the shared clock reference at periodic intervals in the transport stream.

In some embodiments, the transport stream is a Moving Picture Experts Group (MPEG) transport stream (MPEG-TS). The time reference values may include a presentation time stamp (PTS) or a decode time stamp (DTS), or both PTS and DTS values. The shared clock reference may be a program clock reference (PCR) synchronized at the sink device.

Some embodiments are directed to an apparatus for dynamic control of sink device buffering by a source device, including means for determining an application type of a media stream for transmission to a sink device, means for determining, based at least in part on the application type, a buffer size used by the sink device for buffering of a transport stream used for encapsulation of the media stream, means for encoding frames of the media stream with time reference values relative to a shared clock reference based on the determined buffer size, and means for encapsulating the encoded frames in the transport stream.

The means for determining the application type may determine the application type based on an application associated with the media stream. The application type of the media stream may be, for example, a gaming application type, an interactive computing application type, or a media viewing application type. The apparatus may include means for receiving, by an application programming interface of the source device, a call from an application running on the source device for establishing a streaming display connection with the sink device. The means for determining the application type of the media stream may determine the application type based on the received call.

In some embodiments, the apparatus for dynamic control of sink device buffering includes means for determining an off-channel concurrency latency based on a concurrent connection configuration of the source device. The means for determining the buffer size may further determine the buffer size based on the off-channel concurrency latency. In some embodiments, the apparatus includes means for determining a scanning latency based on a channel scanning configuration of the source device. The means for determining the buffer size may further determine the buffer size based on the determined scanning latency.

In some embodiments, the apparatus for dynamic control of sink device buffering includes means for transmitting the transport stream to the sink device over a wireless local area network connection. The apparatus may include means for displaying the media stream at the source device concurrently with encoding of the media stream for transmission to the sink device. The apparatus may include means for transmitting time values of the shared clock reference at periodic intervals in the transport stream.

In some embodiments, the transport stream is a Moving Picture Experts Group (MPEG) transport stream (MPEG-TS). The time reference values may be a presentation time stamp (PTS) or a decode time stamp (DTS), or both PTS and DTS values. The shared clock reference may be a program clock reference (PCR) synchronized at the sink device.

Some embodiments are directed to a device for dynamic control of sink device buffering by a source device, including a processor, and a memory in electronic communication with the processor. The memory may include instructions being executable by the processor to determine an application type of a media stream for transmission to a sink device, determine, based at least in part on the application type, a buffer size used by the sink device for buffering of a transport stream used for encapsulation of the media stream, encode frames of the media stream with time reference values relative to a shared clock reference based on the determined buffer size, and encapsulate the encoded frames in the transport stream.

The memory may include instructions being executable by the processor to determine the application type based on an application associated with the media stream. The application type of the media stream may be, for example, a gaming application type, an interactive computing application type, or a media viewing application type. The memory may include instructions being executable by the processor to receive, by an application programming interface of the source device, a call from an application running on the source device for establishing a streaming display connection with the sink device and determine the application type of the media stream based on the received call.

In some embodiments, the memory includes instructions being executable by the processor to determine an off-channel concurrency latency based on a concurrent connection configuration of the source device, and determine the buffer size further based on the determined off-channel concurrency latency. In some embodiments, the memory includes instructions being executable by the processor to determine a scanning latency based on a channel scanning configuration of the source device, and determine the buffer size further based on the determined scanning latency.

In some embodiments, the memory includes instructions being executable by the processor to transmit the transport stream to the sink device over a wireless local area network connection. The memory may include instructions being executable by the processor to display the media stream at the source device concurrently with encoding of the media stream for transmission to the sink device. The memory may include instructions being executable by the processor to transmit time values of the shared clock reference at periodic intervals in the transport stream.

In some embodiments, the transport stream is a Moving Picture Experts Group (MPEG) transport stream (MPEG-TS). The time reference values may include a presentation time stamp (PTS) or a decode time stamp (DTS), or both PTS and DTS values. The shared clock may be a program clock reference (PCR) synchronized at the sink device.

Some embodiments are directed to a computer program product for dynamic control of sink device buffering by a source device. The computer program product includes a computer-readable medium, including code for determining an application type of a media stream for transmission to a sink device, determining, based at least in part on the application type, a buffer size used by the sink device for buffering of a transport stream used for encapsulation of the media stream, encoding frames of the media stream with time reference values relative to a shared clock reference based on the determined buffer size, and encapsulating the encoded frames in the transport stream.

The computer-readable medium may include code for determining the application type based on an application associated with the media stream. The application type of the media stream may be, for example, a gaming application type, an interactive computing application type, or a media viewing application type. The computer-readable medium may include code for receiving, by an application programming interface of the source device, a call from an application running on the source device for establishing a stream-

ing display connection with the sink device and determining the application type of the media stream based on the received call.

In some embodiments, the computer-readable medium includes code for determining an off-channel concurrency latency based on a concurrent connection configuration of the source device, and determining the buffer size further based on the off-channel concurrency latency. In some embodiments, the computer-readable medium includes code for determining a scanning latency based on a channel scanning configuration of the source device, and determining the buffer size further based on the scanning latency.

In some embodiments, the computer-readable medium includes code for transmitting the transport stream to the sink device over a wireless local area network connection. The computer-readable medium may include code for displaying the media stream at the source device concurrently with encoding of the media stream for transmission to the sink device. The computer-readable medium may include code for transmitting time values of the shared clock reference at periodic intervals in the transport stream.

In some embodiments, the transport stream is a Moving Picture Experts Group (MPEG) transport stream (MPEG-TS). The time reference values may include a presentation time stamp (PTS) or a decode time stamp (DTS), or both PTS and DTS values. The shared clock reference may be a program clock reference (PCR) synchronized at the sink device.

Further scope of the applicability of the described methods and apparatuses will become apparent from the following detailed description, claims, and drawings. The detailed description and specific examples are given by way of illustration only, since various changes and modifications within the spirit and scope of the description will become apparent to those skilled in the art.

BRIEF DESCRIPTION OF THE DRAWINGS

A further understanding of the nature and advantages of the present invention may be realized by reference to the following drawings. In the appended figures, similar components or features may have the same reference label. Further, various components of the same type may be distinguished by following the reference label by a dash and a second label that distinguishes among the similar components. If only the first reference label is used in the specification, the description is applicable to any one of the similar components having the same first reference label irrespective of the second reference label.

FIG. **1** shows a diagram of a system for display of content from one device onto the display of another device by video and/or audio content streaming;

FIG. **2** shows an example system for display of content from a source device to a sink device using application-based control of sink buffering using frame reference timing in accordance with various embodiments;

FIG. **3** shows a diagram illustrating an example transmission of a media stream in the architecture of FIG. **2** in accordance with various embodiments;

FIG. **4** shows a timing diagram that illustrates latency based on concurrency and scanning performed by source device in accordance with various embodiments;

FIG. **5** shows a method for application-based control of sink buffer size using frame reference timing in accordance with various embodiments;

FIG. **6** shows a system architecture for application-based control of sink buffer size using frame reference timing in accordance with various embodiments;

FIG. **7** shows a block diagram illustrating a device for source device control of sink buffer size in accordance with various embodiments;

FIG. **8** shows a block diagram illustrating a device for source device control of sink buffer size in accordance with various embodiments;

FIG. **9** shows a block diagram of a source device configured for dynamic control of sink buffer size in accordance with various embodiments;

FIG. **10** shows a flow chart illustrating an embodiment of a method for dynamic control of sink buffer size in accordance with various embodiments; and

FIG. **11** shows a flow chart illustrating an embodiment of a method **1100** for dynamic control of sink buffer size in accordance with various embodiments.

DETAILED DESCRIPTION

Described embodiments are directed to systems and methods for dynamic control of latency or jitter buffer size at the sink device for audio and/or video streaming over an error-prone channel. The sink buffer size may be dynamically controlled by the source device based on a type of application for a media stream being transmitted from the source device to the sink device for presentation. For example, the techniques may select a buffer size that is smaller for gaming applications, larger for interactive media applications (e.g., interactive computing, presentations, bi-directional communication, etc.), and even larger for non-interactive media types (e.g., streaming video, static images, etc.). The techniques adjust the time delta between a shared clock reference and time reference values of a transport stream that are used by the sink device to determine decoding or presenting of media frames of the transport stream relative to a shared clock reference.

In some embodiments, the source device encapsulates content using an MPEG-TS for transmission over a medium. The source device may adjust the time delta between the PCR and PTS/DTS values in the MPEG-TS to control the amount of latency or jitter buffering at the sink device before decoding and rendering of the content stream. In addition, the techniques may account for transceiver latency at the source device due to scanning or multiple concurrent connections. While application-based sink buffer size control is described with reference to use of a transport stream over Wi-Fi, these techniques may be applied to encoded content transmitted in a transport stream over any wired or wireless transmission medium for which latency buffering may be applied.

In some embodiments, application-based sink buffer size control is implemented via an internal API of the source device. The API may determine a use case or application type by program calls of the application or by monitoring a task manager and may determine an amount of buffering based on the application type. The API may determine concurrency and/or scanning operation of the source device based on parameters associated with communication drivers and may increase the amount of buffering based on the scanning or concurrency operation. The API may notify the encoder and transport stream multiplexor of the buffer time delta and the encoder and multiplexor may associate DTS and/or PTS values with audio and/or video frames of the encoded content in the transport stream according to the

buffer time delta and PCR. In embodiments, a user override may be provided to allow explicit configuration of the buffer time delta.

The following description provides examples, and is not limiting of the scope, applicability, or configuration set forth in the claims. Changes may be made in the function and arrangement of elements discussed without departing from the spirit and scope of the disclosure. Various embodiments may omit, substitute, or add various procedures or components as appropriate. For instance, the methods described may be performed in an order different from that described, and various steps may be added, omitted, or combined. Also, features described with respect to certain embodiments may be combined in other embodiments.

Referring now to FIG. **1**, a system **100** includes a source device **115** and a sink device **135** and may include one or more access points **105**. Examples of the source device **115** may include, but are not limited to, smartphones, cell phones, wireless headphones, wearable computing devices, tablets, personal digital assistants (PDAs), laptops, or any other device capable of communicating with a sink device via a connection (e.g., wired, cellular wireless, Wi-Fi, etc). Examples of the sink devices **135** may include, but are not limited to, in-vehicle infotainment devices, TVs, computers, laptops, projectors, cameras, smartphones, wearable computing devices, or any other device capable of communicating with a source device **115** and displaying content received from the source device **115**. The sink device **135** may be a combination of devices. For example, the sink device **135** may include a display device and a separate device for receiving, buffering, and decoding content for display on the display device.

Source device **115** may be connected to sink device **135** via link **125**. Link **125** is illustrated in FIG. **1** as a wireless link but may be a wired or wireless link, in embodiments. Some wired or wireless links use networking protocols that may have non-deterministic packet transfer timing. For example, some communication links utilize protocols in which a device verifies the absence of other traffic before transmitting on a shared transmission medium, such as an electrical bus, or a band of the electromagnetic spectrum. Arbitration for use of the medium by several devices can cause variation in transmission time from packet to packet. In addition, interference may cause packet loss and re-try, which may result in packet latency or packets being received out of order. While the following techniques are described using the wireless networking architecture illustrated in FIG. **1**, the described techniques are applicable to any suitable wired or wireless communication technology.

In one embodiment, source device **115** is connected to sink device **135** via a Wi-Fi Display connection. Wi-Fi Display, which may be known as Miracast, allows a portable device or computer to transmit video and audio to a compatible display wirelessly. It enables delivery of compressed standard or high-definition video over a wireless link **125**. Wireless link **125** may be a direct wireless link (e.g., peer-to-peer link **125**-*a*), or an indirect wireless link (e.g., indirect link **125**-*b*). Examples of direct wireless links include Wi-Fi Direct connections and connections established by using a Wi-Fi Tunneled Direct Link Setup (TDLS) link. The Wi-Fi devices in these examples may communicate according to the WLAN radio and baseband protocol including physical and MAC layers from IEEE 802.11, and its various versions including, but not limited to, 802-11b, 802.11g, 802.11a, 802.11n, 802.11ac, 802.11ad, 802.11ah, etc.

Miracast allows users to echo the display from one device onto the display of another device by video and/or audio content streaming. The link **125** between the source device **115** and sink device **135** may be bi-directional. In one configuration, the connection between the source device **115** and a sink device **135** may also allow users to launch applications stored on the source device **115** via the sink device **135**. For example, the sink device **135** may include various input controls (e.g., mouse, keyboard, knobs, keys, user interface buttons). These controls may be used at the sink device **135** to initialize and interact with applications stored on the source device **115**.

Miracast may use a transport stream such as an MPEG2 Transport Stream (MPEG-TS). The content may be encoded according to a media encoding format (e.g., h.264, MPEG-4, etc.) and may be multiplexed into the transport stream with other information (e.g., error correction, stream synchronization, etc.) for transmission to the sink device **135**. The source device **115** may maintain a shared clock reference and periodically transmit the reference clock time in the transport stream. The sink device **135** may synchronize a local shared clock reference to the clock reference of the source device **115** using the periodically transmitted reference clock time values. The source device **115** may encode frames of the transport stream with reference values used by the sink device **135** to re-order the frames for decoding and to synchronize output of the media stream relative to the shared reference clock.

As described above, some communication links may have non-deterministic transmission latency or jitter between transmitted packets. For example, latency in shared-medium communication systems may be caused by collisions, retries, packet-loss, and/or arbitration between users for the medium. The transport stream may be buffered at the sink device **135** to reduce rendering issues such as frame skipping or stutter due to packet latency and jitter over the link **125**.

For some interfaces such as Wi-Fi, the source device **115** may scan other channels for other connections or support multiple concurrent connections over multiple channels. For example, the source device **115** may have a Wi-Fi Direct connection for transmitting the content stream to the sink device **135** and may support other concurrent connections to other devices, Wi-Fi access points **105**, or cellular access points. In these instances, the source device **115** may spend a certain amount of time scanning or operating on channels associated with the other connections. In order for the rendered content at the sink device **135** to not be interrupted, the buffer size at the sink device **135** should be large enough to account for time periods where the source device **115** is operating on other channels.

For MPEG-TS, the transport stream contains a clock reference known as the program clock reference (PCR). The PCR is periodically transmitted (e.g., once per 100 ms, etc.) and the sink device synchronizes a local PCR timing clock to the transmitted PCR values. The encoded video and audio frames in the transport stream are associated with a decode time known as the decode time stamp (DTS) and a presentation time known as the presentation time stamp (PTS). The sink device decodes and presents audio and video elements based on the DTS and PTS associated with the audio and video frames relative to the PCR. For example, the sink device **135** may display decoded audio and/or video frames when PTS values associated with the frames correspond to the PCR. Similarly, DTS values may be used at the sink device **135** to determine when the frames are decoded.

The system **100** including the source device **115** may be configured to dynamically control latency or jitter buffer size at the sink device **135** for audio and/or video streaming over an error-prone channel. The sink buffer size may be dynamically controlled by the source device **115** based on a type of application for a media stream being transmitted from the source device **115** to the sink device **135** for presentation. For example, the techniques may select a buffer size that is smaller for gaming applications, larger for interactive media applications (e.g., interactive computing, presentations, bi-directional communication, etc.), and even larger for non-interactive media types (e.g., streaming video, static images, etc.). The techniques adjust the time delta between a shared clock reference and time reference values of a transport stream that are used by the sink device to determine decoding or presenting of media frames of the transport stream relative to a shared clock reference.

In embodiments, the source device encapsulates content using an MPEG-TS for transmission over a medium. The source device may adjust the time delta between the PCR and PTS/DTS values in the MPEG-TS to control the amount of latency or jitter buffering at the sink device before decoding and rendering of the content stream. In addition, the techniques may account for transceiver latency at the source device due to scanning or multiple concurrent connections. While application-based sink buffer size control is described with reference to use of a transport stream over Wi-Fi, these techniques may be applied to encoded content transmitted in a transport stream over any wired or wireless transmission medium for which latency buffering may be applied.

In some embodiments, application-based sink buffer size control is implemented via an internal API of the source device. The API may determine a use case or application type by program calls of the application or by monitoring a task manager and may determine an amount of buffering based on the application type. The API may determine concurrency and/or scanning operation of the source device based on parameters associated with communication drivers and may increase the amount of buffering based on the scanning or concurrency operation. The API may notify the encoder and transport stream multiplexor of the buffer time delta and the encoder and multiplexor may associate DTS and/or PTS values with audio and/or video frames of the encoded content in the transport stream according to the buffer time delta and PCR. In embodiments, a user override may be provided to allow explicit configuration of the buffer time delta.

FIG. **2** illustrates an example system **200** for display of content from a source device **115**-*a* to a sink device **135**-*a* using application-based control of sink buffer size using encapsulated frame reference timing in accordance with various embodiments. FIG. **2** may illustrate streaming of content from a source device **115**-*a* to a sink device **135**-*a* over a Wi-Fi connection **125**-*c* using a transport stream such as an MPEG2 Transport Stream (MPEG-TS). The Wi-Fi connection **125**-*c* may be direct (e.g., Wi-Fi Direct, etc.) or indirect (e.g., via a Wi-Fi access point **105** or other device, etc.). The content may be encoded according to a media encoding format (e.g., h.264, MPEG-4, etc.) and may be multiplexed into a transport stream (e.g., MPEG-TS, etc.) for transmission.

The source device **115**-*a* may include a system clock reference **205** (e.g., PCR), one or more applications **215**, sink buffer size module **210**, audio/video encoder **225**, transport stream multiplexor **235**, transceiver **240**, output device **280** (e.g., display device, speaker, etc.), and antenna(s) **245**. The sink device **135**-*a* may include antenna(s) **295**, transceiver **290**, transport stream de-multiplexor **255**, clock reference **260**, buffer **265**, audio/video decoder **270**, and output device **285** (e.g., display device, speaker, etc.). As described above, source device **115**-*a* may encode a content stream **220** from an application **215** according to an encoding format and may encapsulate the encoded video into transport stream **230**. Clock reference values from the clock reference **205** may be transmitted periodically in transport stream **230**. The sink device **135**-*a* may synchronize the local clock reference **260** to the clock reference **205** of the source device **115**-*a*. The source device **115**-*a* may also present the content from application **215** on output device **280** (e.g., display device, speaker, etc.).

FIG. **3** is a diagram **300** illustrating an example transmission of a media stream in the architecture of system **200** in accordance with various embodiments. As illustrated in FIG. **3**, application **215** may generate media stream **220** which may be, for example, a stream of video frames **305**. The media stream may have a frame rate of $1/t_F$ (e.g., 30 Hz, 60 Hz, etc.).

Media stream **220** may be input into encoder **225**, which may generate an encoded media stream **320**. Encoder **225** may use an encoding format that may compress media stream **220** and may use different types of encoded frames which may have different levels of compression. For example, diagram **300** illustrates encoded media stream **320** having Intra (I) frames which contain information for a full image of a video stream, Predicted (P) frames which are predicted from past I or P frames, and Bi-directional Predicted (B) frames which use past and future I and P frames for motion compensation and offer the greatest compression. The encoder **225** may re-order the encoded frames for transmission based on the order in which the frames are used for decoding. For example, timing diagram **300** illustrates that I and/or P frames may be re-ordered before B frames in the encoded media stream **320**.

The encoded media stream **320** may be encapsulated into a transport stream format (e.g., MPEG-TS, etc.) by transport stream multiplexor **235**. The transport stream **230** is then sent to transceiver **240** for transmission to the sink device **135**-*a* via transmission link **125**-*c*. The transport stream **230** may include time reference values associated with the encapsulated frames for decoding and display of the frames based on a shared clock reference (e.g., PCR **205**, etc.). The transport stream **230** may also include periodic transmission of reference clock values for synchronization of the local shared clock reference at the sink device **135**-*a*. As illustrated in diagram **300**, the MPEG-TS transport stream **230** may include PTS and/or DTS values **330** associated with each of the frames in the transport stream. The PTS and/or DTS values **330** may be encoded in packets of the transport stream **230**. The transport stream **230** may include PCR values **310**-*a* and **310**-*b*, which may be used by the sink device **135**-*a* to synchronize a local PCR **260** to the PCR **205** at the source device **115**-*a*.

As described above, the received transport stream **250** at the sink device **135**-*a* may have variable latency and jitter in packet transmission over the transmission link **125**-*c*. For example, diagram **300** shows variable latency in receipt of packets in the received transport stream **250**. At the sink device **135**-*a*, the received transport stream **250** may be buffered and decoded. The sink device **135**-*a* may buffer packets of the received transport stream **250** prior to decoding. Additionally or alternatively, it may decode the received packets and buffer the decoded media stream **275** prior to output of the decoded media stream **275** on the output device

285. Frames of the decoded media stream **275** in the sink device **135**-*a* may be displayed on the display **285** according to their associated PTS values.

Source device **115**-*a* may determine a sink buffer size t_{BUF} **340** based on the use case of the media stream **220** (e.g., via sink buffer size module **210**). The use case of the media stream may be determined based on the type of application **215**. For example, source device **115**-*a* may select a higher sink buffer size t_{BUF} **340** for more buffering at the sink device **135**-*a* for non-interactive multimedia display and other latency tolerant applications and media streams. Source device **115**-*a* may select a lower sink buffer size t_{BUF} **340** for less buffering at the sink device **135**-*a* for applications and media streams such as interactive computer or gaming that are less latency tolerant. For example, source device **115**-*a* may select a sink buffer size t_{BUF} **340** of 200-500 milliseconds (ms) for multimedia viewing (e.g., video and/or audio playback or streaming, etc.), 80-200 ms for interactive computing (e.g., power-point, etc.), and 40-80 ms for gaming. These are merely illustrative examples and source device **115**-*a* may have more or fewer categories for selecting sink buffer size t_{BUF} **340** and may select other values for various categories.

Source device **115**-*a* may also select sink buffer size t_{BUF} **340** using other factors including the selected transmission medium (e.g., Wi-Fi vs. power line, etc.), the capacity of the communication link (e.g., in bps, etc.), the data rate of the media stream (e.g., in bps, etc.), the encoding format, or channel conditions (e.g., measured, etc.) that may affect jitter of communications using the transmission medium.

Source device **115**-*a* may determine decode time reference values (e.g., DTS, etc.) and presentation time reference values (e.g., PTS, etc.) for frames of the transport stream **230** based on the determined sink buffer size t_{BUF} **340** and a decode order of the frames. The decode time reference values and presentation time reference values may be multiplexed with the frames of the transport stream as illustrated by time reference values **330** for each transport stream frame **325**. Notably, by using the presentation time reference values and/or decode time reference values of the transport stream, the source device **115**-*a* does not have to communicate the sink buffer size t_{BUF} **340** to the sink device **135**-*a* prior to transmitting the transport stream. In addition, sink devices do not need to support additional features for source device control of sink buffer size. The sink buffer size is controlled through the presentation time reference values and/or decode time reference values already used by the transport stream protocol for synchronization of output of media content.

The presentation time reference values for transmission in the transport stream may be determined by the value of the reference clock (e.g., PCR, etc.) when the frame is transmitted and the sink buffer size t_{BUF} **340**. The decode time reference values may be determined by the value of the reference clock (e.g., PCR, etc.), the sink buffer size t_{BUF} **340**, and may indicate the order for decoding. The decode time reference values may account for the decode time (t_{DEC}), which may vary based on the type of encoding (e.g., number of B frames, etc.). Table 1 shows calculated values for presentation time reference values (e.g., PTS, etc.) and decode time reference values (e.g., DTS, etc.) of transport stream frames **325**, according to one example. In the example shown in FIG. **3**, the decoded media stream **275** is displayed on sink device **135**-*a* with $t_{BUF}=6 \cdot t_F$.

TABLE 1

Frame	DTS	PTS
325-a	$N + t_{BUF} - t_{DEC}$	$N + t_{BUF}$
325-b	$N + t_{BUF} + t_F - t_{DEC}$	$N + t_{BUF} + 3 \cdot t_F$
325-c	$N + t_{BUF} + 2 \cdot t_F - t_{DEC}$	$N + t_{BUF} + t_F$
325-d	$N + t_{BUF} + 3 \cdot t_F - t_{DEC}$	$N + t_{BUF} + 2 \cdot t_F$
325-e	$N + t_{BUF} + 4 \cdot t_F - t_{DEC}$	$N + t_{BUF} + 6 \cdot t_F$
325-f	$N + t_{BUF} + 5 \cdot t_F - t_{DEC}$	$N + t_{BUF} + 4 \cdot t_F$
325-g	$N + t_{BUF} + 6 \cdot t_F - t_{DEC}$	$N + t_{BUF} + 5 \cdot t_F$
325-h	$N + t_{BUF} + 7 \cdot t_F - t_{DEC}$	$N + t_{BUF} + 9 \cdot t_F$
325-i	$N + t_{BUF} + 8 \cdot t_F - t_{DEC}$	$N + t_{BUF} + 7 \cdot t_F$
325-j	$N + t_{BUF} + 9 \cdot t_F - t_{DEC}$	$N + t_{BUF} + 8 \cdot t_F$

Source device **115**-*a* may include user settings that allow the user to select preferences related to the amount of buffering at the sink device **135**-*a*. For example, the user may be able to choose a preference between lower latency or higher reliability display of the media stream and the source device **115**-*a* may adjust the sink buffer size t_{BUF} **340** accordingly. The user may be able to set sink buffer size preferences based on the use categories, for individual applications, or for individual media streams. Additionally or Alternatively, the user may be able to associate particular applications with application types. In some examples, the user may be able to set the sink buffer size t_{BUF} **340** directly (e.g., in ms, etc.).

Source device **115**-*a* may also vary sink buffer size t_{BUF} **340** based on concurrency and scanning configuration. FIG. **4** shows a timing diagram **400** that illustrates latency based on concurrency and scanning performed by a source device **115** (e.g., source device **115**-*a* illustrated in FIG. **2**, etc.). In timing diagram **400**, source device **115** may be transmitting a transport stream on channel **410**-*a* to a sink device **135** while also maintaining a concurrent connection with another device or access point over channel **410**-*b*. After transmission of packets of the transport stream in data transmission **415**-*a* over channel **410**-*a*, the source device **115** may switch to transmit or receive data **420** on channel **410**-*b*.

Source device **115** may determine an off-channel concurrency time t_{CON} **430** for which the source device **115** will switch from the connection link for transmitting the transport stream over channel **410**-*a* to transmit or receive data in service of the concurrent connection link. The off-channel concurrency time t_{CON} **430** may represent, for example, a time period for switching channels, handshaking with the other devices or access points, and transfer of one or more data packets. In some examples, source device **115** may increase the offset **340** by approximately 60 ms for supporting off-channel concurrency. Where the source device **115** supports multiple concurrent connections (e.g., K other connections, etc.) in addition to the connection link with the sink device **135**, the off-channel concurrency time t_{CON} **430** may be added to the sink buffer size t_{BUF} **340** for each concurrent connection supported. For example, the total off-channel concurrency time may be given by:

$$t_{CON} = \sum_{i=1}^{K} t_{CON}[i]$$

Alternatively, one off-channel concurrency time t_{CON} **430** may be added to the sink buffer size t_{BUF} **340** regardless of the number of connections, or the off-channel concurrency time t_{CON} **430** added for each connection may be reduced by a scaling factor F. For example, the total off-channel concurrency time may be given by:

$$t_{CON} = \sum_{i=1}^{K} F \cdot t_{CON}[i]$$

Source device **115** may also be associated with one or more access points **105** and may perform active or passive scanning **425** of channels of the access points **105**. For example, timing diagram **400** shows that, after performing data transfer **415**-*b*, source device **115** performs scanning **425**-*a* and **425**-*b* on channels **410**-*c* and **410**-*d*, respectively. Source device **115** may perform data transfer **415**-*c* over channel **410**-*a*. Source device **115** may determine a scanning time t_{SCAN} **440** for which the source device **115** will switch from the connection link for transmitting the transport stream over channel **410**-*a* to scanning one or more channels associated with the access points **105**. The scanning time t_{SCAN} **440** may increase channel latency by, for example, approximately 110 ms for passive scanning and approximately 50 ms for active scanning.

Where source device **115** has concurrent connections with other devices and access points for which scanning is required, the source device **115** may determine the additional latency to be added to sink buffer size t_{BUF} **340** in a variety of ways. In one example, additional latency for sink buffer size t_{BUF} **340** may be determined according to the sum of off-channel concurrency time t_{CON} **430** and scanning time t_{SCAN} **440**. Alternatively, the additional latency may be determined according to the higher of the off-channel concurrency time t_{CON} **430** and scanning time t_{SCAN} **440**. This technique may be selected, for example where the capacity of the link is high relative to the data rate of the transport stream.

FIG. **5** illustrates a method **500** for application-based control of sink buffer size using frame reference timing in accordance with various embodiments. Method **500** may be employed, for example, by the source devices **115** of FIG. **1** or FIG. **2**. In one implementation, the sink buffer size module **210** or the devices **700** or **800** described with reference to FIG. **2**, FIG. **7** or FIG. **8** may execute one or more sets of codes to control the functional elements of a source device **115** to perform the functions described below.

At block **505** of method **500**, the source device **115** determines a use case for a media stream. The source device **115** may determine the use case based on a type of application associated with the media stream. For example, the source device **115** may determine whether the associated application is used for multimedia playback, interactive computing, gaming, or other use case.

At block **510**, the source device **115** determines the sink buffer size based on the use case of the media stream. For example, the source device **115** may select a higher sink buffer size for non-interactive multimedia display and other latency tolerant applications and media streams and lower sink buffer size for applications and media streams such as interactive computer or gaming that are less latency tolerant. The source device may receive user input associated with the user's preferences of lower latency or higher reliability media transfer and may adjust the sink buffer size accordingly.

At block **515**, the source device **115** may determine if other connections are concurrently supported that will result in latency to the media stream. For example, where the source device **115** is using a Wi-Fi Display connection to transmit the media stream to the sink device **135**, the source device **115** may determine if other Wi-Fi connections are concurrently supported and the effect of the concurrently supported connections on latency of the Wi-Fi Display connection. If other connections are concurrently supported, the source device **115** adds a time period t_{CON} to the sink buffer size at block **520**. The time period t_{CON} may be added for each additionally supported connection, or may be scaled for multiple additional concurrent connections.

At block **525**, the source device **115** may determine if scanning is to be performed based on associations with wireless access points. For example, the source device **115** may be currently connected to an access point **105** and may determine that active or passive scanning is to be performed for channels associated with the access point **105**. If scanning is to be performed, the source device **115** may add the scanning time t_{SCAN} to the sink buffer size at block **530**.

At block **530**, the source device **115** transmits the media stream in a transport stream format with frames of the transport stream associated with presentation time reference values calculated based on the determined sink buffer size from blocks **510**, **515**, **520**, **525**, and/or **530**. The source device **115** may associate the frames of the transport stream with decode time reference values calculated based on the determined sink buffer size, frame decode order, and decode time.

FIG. **6** illustrates a system architecture **600** for application-based control of sink buffer size using frame reference timing in accordance with various embodiments. System architecture **600** may include application layer **610**, latency buffer API **620**, and operating system (OS) subsystems and hardware layer **630**. System architecture **600** may illustrate, for example, a layer stack for implementation of application-based control of sink buffer size using frame reference timing in the source devices **115** of FIG. **1** or FIG. **2**.

When applications (e.g., application **615**, etc.) are preparing to transmit a media stream to a sink device, latency buffer API **620** may determine the use case of the media stream (e.g., by application type, etc.). For example, the application **615** may call the latency buffer API **620** as part of setting up the transport stream for transmission of the media stream, or the latency buffer API **620** may query the task manager to determine when application **615** is establishing a transport stream for transmitting a media stream to a sink device **135** for output. Delay manager **625** may determine a sink buffer size t_{BUF} for the transport stream based on the use case of the media stream. Delay manager **625** may determine a presentation offset to apply to packets of a transport stream used to transmit the media stream to the sink device **135** based on the sink buffer size t_{BUF}. Latency buffer API **620** may be, for example, a component of a mobile device at the mobile OS service layer.

Latency buffer API **620** may query the wireless driver manager **635** to determine the concurrency and scanning configuration of the device. Delay manager **625** may determine an off-channel concurrency time t_{CON} and/or scanning time t_{SCAN} based on the concurrency and scanning configuration. Delay manager **625** may increase the presentation offset to account for the off-channel concurrency time t_{CON} and/or scanning time t_{SCAN}.

Delay manager **625** may notify the encoder **225** and transport stream multiplexor **235** of the presentation offset for the frames of the media stream. The encoder **225** and transport stream multiplexor **235** may generate decode time reference values (e.g., DTS, etc.) and presentation time reference values (e.g., PTS, etc.) for frames of the transport stream based on the determined presentation offset and the clock reference (e.g., PCR, etc.).

User override **645** may allow the user to choose a preference between lower latency or higher reliability display of the media stream and the delay manger **625** may adjust the presentation offset accordingly. The user may be able to set sink-device buffering preferences based on the use categories, for individual applications, or for individual media streams. In some examples, user override **645** may allow the user to set the presentation offset directly (e.g., in ms, etc.).

FIG. **7** is a block diagram illustrating a device **700** for source device control of sink buffer size in accordance with various embodiments. The device **700** may be an example of one or more aspects of one of the source devices **115** described with reference to FIG. **1** or FIG. **2**. The device **700** may also be a processor. The device **700** may include a content use case module **705**, a latency buffer size module **710**, an encoder module **715**, and an encapsulation module **720**. Each of these components may be in communication with each other.

Content use case module **705** may determine a use case for a media stream to be transmitted to a sink device for output (e.g., display, etc.) at the sink device. Content use case module **705** may determine the use case based on a type of application associated with the media stream. For example, content use case module **705** may determine whether the associated application is used for multimedia playback, interactive computing, gaming, or other use case.

Latency buffer size module **710** may determine a sink buffer size based on the use case of the media stream. For example, the source device **115** may select a higher presentation offset for non-interactive multimedia display and other latency tolerant applications and media streams and lower presentation offset for applications and media streams such as interactive computer or gaming that are less latency tolerant. Latency buffer size module **710** may provide the presentation offset to the encoder module **715** and encapsulation module **720**.

Encoder module **715** may encode frames of the media stream and encapsulation module **720** may encapsulate the encoded frames into a transport stream for transmission to the sink device. The encoded frames may be associated with time reference values (e.g., PTS, DTS, etc.) in the transport stream, where the associated time reference values are offset from a shared clock reference by values determined from the presentation offset.

FIG. **8** is a block diagram illustrating a device **800** in accordance with various embodiments. The device **800** may be an example of one or more aspects of one of the source devices **115** described with reference to FIG. **1** or FIG. **2**. The device **800** may also be a processor. The device **800** may include a content use case module **705**-*a*, a latency buffer size module **710**-*a*, an encoder module **715**-*a*, an encapsulation module **720**-*a*, and a scan/concurrency latency module **805**. Each of these components may be in communication with each other.

The device **800** may be configured to implement aspects discussed above with respect to device **700** of FIG. **7** and may not be repeated here for the sake of brevity. For example, the content use case module **705**-*a*, latency buffer size module **710**-*a*, encoder module **715**-*a*, and encapsulation module **720**-*a* may be examples of the content use case module **705**, latency buffer size module **710**, encoder module **715**, and encapsulation module **720** of FIG. **7**.

Scan/concurrency latency module **805** may determine an off-channel concurrency time t_{CON} and/or scanning time t_{SCAN} based on the concurrency and scanning configuration. Scan/concurrency latency module **805** may communicate the off-channel concurrency time t_{CON} and/or scanning time t_{SCAN} to the latency buffer size module **710**-*a*. The latency buffer size module **710**-*a* may determine the sink buffer size based on the use case of the media stream received from the content use case module **705**-*a* and further based on the off-channel concurrency time t_{CON} and/or scanning time t_{SCAN} as described above with reference to FIG. **4**.

The components of the devices **700** and **800** may, individually or collectively, be implemented with one or more application-specific integrated circuits (ASICs) adapted to perform some or all of the applicable functions in hardware. Alternatively, the functions may be performed by one or more other processing units (or cores), on one or more integrated circuits. In other embodiments, other types of integrated circuits may be used (e.g., Structured/Platform ASICs, Field Programmable Gate Arrays (FPGAs), and other Semi-Custom ICs), which may be programmed in any manner known in the art. The functions of each unit may also be implemented, in whole or in part, with instructions stored in a memory, formatted to be executed by one or more general or application-specific processors.

FIG. **9** is a block diagram **900** of a source device **115**-*b* configured for dynamic control of sink buffer size in accordance with various embodiments. Source device **115**-*b* may be, for example, the source device **115** of FIG. **1** or FIG. **2**. The source device **115**-*b* may have any of various configurations, such as personal computers (e.g., laptop computers, netbook computers, tablet computers, etc.), smartphones, cellular telephones, PDAs, wearable computing devices, digital video recorders (DVRs), internet appliances, gaming consoles, e-readers, etc. The source device **115**-*b* may have an internal power supply (not shown), such as a small battery, to facilitate mobile operation.

The source device **115**-*b* includes antenna(s) **245**-*a*, a transceiver module **240**-*a*, memory **920**, a processor module **970**, and I/O devices **980**, which each may be in communication, directly or indirectly, with each other (e.g., via one or more buses). The transceiver module **240**-*a* is configured to communicate bi-directionally, via the antennas **245**-*a* and/or one or more wired or wireless links, with one or more networks, as described above. For example, the transceiver module **240**-*a* may be configured to communicate bi-directionally with sink devices **135** of FIG. **1** or FIG. **2**. The transceiver module **240**-*a* may include a modem configured to modulate the packets and provide the modulated packets to the antennas **245**-*a* for transmission, and to demodulate packets received from the antennas **245**-*a*. The transceiver module **240**-*a* may be configured to maintain multiple concurrent communication links using the same or different radio interfaces (e.g., Wi-Fi, cellular, etc.). The source device **115**-*b* may include a single antenna **245**-*a*, or the source device **115**-*b* may include multiple antennas **245**-*a*. The source device **115**-*b* may be capable of employing multiple antennas **245**-*a* for transmitting and receiving communications in a MIMO communication system.

The memory **920** may include random access memory (RAM) and read-only memory (ROM). The memory **920** may store computer-readable, computer-executable software code **925** containing instructions that are configured to, when executed, cause the processor module **970** to perform various functions described herein (e.g., Wi-Fi Display, dynamic configuration of sink buffer size, etc.). Alternatively, the software **925** may not be directly executable by the processor module **970** but be configured to cause the computer (e.g., when compiled and executed) to perform functions described herein.

The processor module **970** may include an intelligent hardware device, e.g., a central processing unit (CPU), a

microcontroller, an application specific integrated circuit (ASIC), etc. The processor module **970** may include a speech encoder (not shown) configured to receive audio via a microphone, convert the audio into packets (e.g., 30 ms in length) representative of the received audio, provide the audio packets to the transceiver module **240**-*a*, and provide indications of whether a user is speaking. Alternatively, an encoder may only provide packets to the transceiver module **240**-*a*, with the provision or withholding/suppression of the packet itself providing the indication of whether a user is speaking.

According to the architecture of FIG. **9**, the source device **115**-*b* further includes content use case module **705**-*b*, latency buffer size module **710**-*b*, scan/concurrency latency module **805**-*a*, encoder module **715**-*b*, and encapsulation module **720**-*b*. By way of example, these modules may be components of the source device **115**-*b* in communication with some or all of the other components of the source device **115**-*b* via bus **975**. Additionally or Alternatively, functionality of these modules may be implemented as a component of the transceiver module **240**-*a*, as a computer program product, and/or as one or more controller elements of the processor module **970**.

Content use case module **705**-*b* may determine a use case for a media stream to be transmitted to a sink device **135** for output (e.g., display, etc.) at the sink device **135**. Content use case module **705**-*b* may determine the use case based on a type of application associated with the media stream. For example, content use case module **705**-*b* may determine whether the associated application is used for multimedia playback, interactive computing, gaming, or other use case. The media stream may be concurrently output at the source device via I/O devices **980**.

Latency buffer size module **710**-*b* may determine a sink buffer size based on the use case of the media stream. For example, the latency buffer size module **710**-*b* may select a higher sink buffer size for non-interactive multimedia display and other latency tolerant applications and media streams and lower sink buffer size for applications and media streams such as interactive computer or gaming that are less latency tolerant. Latency buffer size module **710**-*b* may provide the sink buffer size to the encoder module **715**-*b* and encapsulation module **720**-*b*.

Encoder module **715**-*b* may encode frames of the media stream and encapsulation module **720**-*b* may encapsulate the encoded frames into a transport stream for transmission to the sink device. The encoded frames may be associated with time reference values (e.g., PTS, DTS, etc.) in the transport stream, where the associated time reference values are offset from a shared clock reference by values determined from the sink buffer size.

Scan/concurrency latency module **805**-*a* may determine an off-channel concurrency time t_{CON} and/or scanning time t_{SCAN} based on the concurrency and scanning configuration. Scan/concurrency latency module **805**-*a* may communicate the off-channel concurrency time t_{CON} and/or scanning time t_{SCAN} to the latency buffer size module **710**-*b*. The latency buffer size module **710**-*b* may determine the sink buffer size based on the use case of the media stream received from the content use case module **705**-*b* and further based on the off-channel concurrency time t_{CON} and/or scanning time t_{SCAN}.

The components of the source device **115**-*b* may, individually or collectively, be implemented with one or more application-specific integrated circuits (ASICs) adapted to perform some or all of the applicable functions in hardware. Alternatively, the functions may be performed by one or more other processing units (or cores), on one or more integrated circuits. In other embodiments, other types of integrated circuits may be used (e.g., Structured/Platform ASICs, Field Programmable Gate Arrays (FPGAs), and other Semi-Custom ICs), which may be programmed in any manner known in the art. The functions of each unit may also be implemented, in whole or in part, with instructions embodied in a memory, formatted to be executed by one or more general or application-specific processors. Each of the noted modules may be a means for performing one or more functions related to operation of the source device **115**-*b*.

FIG. **10** is a flow chart illustrating an embodiment of a method **1000** for dynamic control of sink buffer size in accordance with various embodiments. For clarity, the method **1000** is described below with reference to the source devices **115** of FIG. **1**, FIG. **2**, or FIG. **9**, and/or the devices **700** or **800** of FIG. **7** or FIG. **8**. In one implementation, the devices **700** or **800** described with reference to FIG. **7** or FIG. **8** may execute one or more sets of codes to control the functional elements of a source device **115** to perform the functions described below.

At block **1005** of method **1000**, an application type of a media stream for transmission to a sink device **135** may be determined. For example, a source device **115** may determine whether an application associated with the media stream is used for multimedia playback, interactive computing, gaming, or other use case. The application type may be determined by an API of the source device based on a call from the application or from monitoring the task manager.

At block **1010**, a buffer size for buffering the transport stream at the sink device **135** is determined based on the application type. For example, a source device **115** may select a higher sink buffer size for non-interactive multimedia display and other latency tolerant applications and media streams and lower sink buffer size for applications and media streams such as interactive computer or gaming that are less latency tolerant.

At block **1015**, frames of the media stream are encoded and may be associated with time reference values relative to a shared clock reference based on the determined sink buffer size. For example, decode time reference values (e.g., DTS, etc.) and presentation time reference values (e.g., PTS, etc.) may be determined for frames of the encoded media stream based on the determined sink buffer size and the clock reference (e.g., PCR, etc.).

At block **1020**, the encoded frames may be encapsulated in a transport stream (e.g., MPEG-TS, etc.) for transmission to the sink device **135**. The source device **115** may transmit the transport stream to the sink device **135** over a connection link (e.g., Wi-Fi Display connection, etc.) supporting the transport stream for output at the sink device **135**.

FIG. **11** is a flow chart illustrating an embodiment of a method **1100** for dynamic control of sink buffer size in accordance with various embodiments. For clarity, the method **1100** is described below with reference to the source devices **115** of FIG. **1**, FIG. **2**, or FIG. **9**, and/or the devices **700** or **800** of FIG. **7** or FIG. **8**. In one implementation, the devices **700** or **800** described with reference to FIG. **7** or FIG. **8** may execute one or more sets of codes to control the functional elements of a source device **115** to perform the functions described below.

At block **1105** of method **1100**, an application type of a media stream for transmission to a sink device may be determined. For example, a source device may determine whether an application associated with the media stream is used for multimedia playback, interactive computing, gaming, or other use case. The application type may be deter-

mined by an API of the source device based on a call from the application or from monitoring the task manager.

At block **1110**, the source device **115** may determine an off-channel concurrency latency based on a concurrent connection configuration of the source device. For example, where the source device **115** is using a Wi-Fi Display connection to transmit the media stream to the sink device **135**, the source device **115** may determine if other Wi-Fi connections or cellular network connections are concurrently supported and the effect of the concurrently supported connections on latency of the Wi-Fi Display connection.

At block **1115**, the source device **115** may determine a scanning latency based on a scanning configuration of the source device. For example, the source device **115** may be currently connected to an access point **105** and may determine that active or passive scanning is to be performed for channels associated with the access point **105**.

At block **1120**, the source device **115** determines a buffer size for buffering the transport stream at the sink device **135** based on the application type, the off-channel concurrency latency, and/or the scanning latency. For example, the source device **115** may determine an application-based sink buffer size based on the determined application type of the media stream and may add the off-channel concurrency latency and the scanning latency to the application-based sink buffer size to determine the sink buffer size to be used for encapsulation of the media stream into a transport stream.

At block **1125**, frames of the media stream are encoded and may be associated with time reference values relative to a shared clock reference based on the determined sink buffer size. For example, decode time reference values (e.g., DTS, etc.) and presentation time reference values (e.g., PTS, etc.) may be determined for frames of the encoded media stream based on the determined sink buffer size and the clock reference (e.g., PCR, etc.).

At block **1130**, the encoded frames may be encapsulated in a transport stream (e.g., MPEG-TS, etc.) for transmission to the sink device **135**. The source device **115** may transmit the transport stream to a sink device **135** over a connection link (e.g., Wi-Fi Direct connection, etc.) supporting the transport stream for output at the sink device **135**.

The detailed description set forth above in connection with the appended drawings describes exemplary embodiments and does not represent the only embodiments that may be implemented or that are within the scope of the claims. The term "exemplary" used throughout this description means "serving as an example, instance, or illustration," and not "preferred" or "advantageous over other embodiments." The detailed description includes specific details for the purpose of providing an understanding of the described techniques. These techniques, however, may be practiced without these specific details. In some instances, well-known structures and devices are shown in block diagram form in order to avoid obscuring the concepts of the described embodiments.

Information and signals may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the above description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

The various illustrative blocks and modules described in connection with the disclosure herein may be implemented or performed with a general-purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, multiple microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

The functions described herein may be implemented in hardware, software executed by a processor, firmware, or any combination thereof. If implemented in software executed by a processor, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Other examples and implementations are within the scope and spirit of the disclosure and appended claims. For example, due to the nature of software, functions described above can be implemented using software executed by a processor, hardware, firmware, hardwiring, or combinations of any of these. Features implementing functions may also be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations. Also, as used herein, including in the claims, "or" as used in a list of items prefaced by "at least one of" indicates a disjunctive list such that, for example, a list of "at least one of A, B, or C" means A or B or C or AB or AC or BC or ABC (i.e., A and B and C).

Computer-readable media includes both computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A storage medium may be any available medium that can be accessed by a general purpose or special purpose computer. By way of example, and not limitation, computer-readable media can comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to carry or store desired program code means in the form of instructions or data structures and that can be accessed by a general-purpose or special-purpose computer, or a general-purpose or special-purpose processor. Also, any connection is properly termed a computer-readable medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium. Disk and disc, as used herein, include compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk and blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above are also included within the scope of computer-readable media.

The previous description of the disclosure is provided to enable a person skilled in the art to make or use the disclosure. Various modifications to the disclosure will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other variations without departing from the spirit or scope of the disclosure. Throughout this disclosure the term "example" or "exemplary" indicates an example or instance and does not imply or require any preference for the noted example. Thus, the

disclosure is not to be limited to the examples and designs described herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

What is claimed is:

1. A method performed by a source device, comprising:
determining an application type of a media stream for transmission to a sink device;
determining at least one of an off-channel concurrency latency based at least in part on a concurrent connection configuration of the source device or a scanning latency using a channel scanning configuration of the source device;
determining, based at least in part on the application type and at least one of the off-channel concurrency latency or the scanning latency, a buffer size used by the sink device for buffering of a transport stream used for encapsulation of the media stream;
encoding frames of the media stream with time reference values relative to a shared clock reference using the determined buffer size; and
encapsulating the encoded frames in the transport stream.

2. The method of claim **1**, comprising:
determining the off-channel concurrency latency based at least in part on the concurrent connection configuration of the source device,
wherein determining the buffer size is further based on the determined off-channel concurrency latency.

3. The method of claim **1**, comprising:
determining the scanning latency using the channel scanning configuration of the source device,
wherein determining the buffer size is further based on the determined scanning latency.

4. The method of claim **1**, further comprising:
transmitting the transport stream to the sink device over a wireless local area network connection.

5. The method of claim **4**, further comprising:
displaying the media stream at the source device concurrently with encoding of the media stream for transmission to the sink device.

6. The method of claim **4**, further comprising:
transmitting time values of the shared clock reference at periodic intervals in the transport stream.

7. The method of claim **1**, wherein determining the application type is based at least in part on an application associated with the media stream.

8. The method of claim **1**, wherein the application type of the media stream is one of a gaming application type, an interactive computing application type, or a media viewing application type.

9. The method of claim **1**, wherein the transport stream comprises a Moving Picture Experts Group (MPEG) transport stream (MPEG-TS).

10. The method of claim **1**, wherein the time reference values comprise one or more of a presentation time stamp (PTS) or a decode time stamp (DTS), or a combination thereof.

11. The method of claim **1**, wherein the shared clock reference comprises a program clock reference (PCR) synchronized at the sink device.

12. The method of claim **1**, further comprising:
receiving, by an application programming interface of the source device, a call from an application running on the source device for establishing a streaming display connection with the sink device, and
wherein determining the application type of the media stream is based on the received call.

13. An apparatus for dynamic control of sink device buffering by a source device, the apparatus comprising:
means for determining an application type of a media stream for transmission to a sink device;
means for determining at least one of an off-channel concurrency latency based at least in part on a concurrent connection configuration of the source device or a scanning latency using a channel scanning configuration of the source device;
means for determining, based at least in part on the application type and at least one of the off-channel concurrency latency or the scanning latency, a buffer size used by the sink device for buffering of a transport stream used for encapsulation of the media stream;
means for encoding frames of the media stream with time reference values relative to a shared clock reference using the determined buffer size; and
means for encapsulating the encoded frames in the transport stream.

14. The apparatus of claim **13**, comprising:
means for determining the off-channel concurrency latency based at least in part on the concurrent connection configuration of the source device,
wherein the means for determining the buffer size further determines the buffer size based on the determined off-channel concurrency latency.

15. The apparatus of claim **13**, comprising:
means for determining the scanning latency using the channel scanning configuration of the source device,
wherein the means for determining the buffer size further determines the buffer size based on the determined scanning latency.

16. The apparatus of claim **13**, further comprising:
means for transmitting the transport stream to the sink device over a wireless local area network connection.

17. The apparatus of claim **16**, further comprising:
means for displaying the media stream at the source device concurrently with encoding of the media stream for transmission to the sink device.

18. The apparatus of claim **16**, further comprising:
means for transmitting time values of the shared clock reference at periodic intervals in the transport stream.

19. The apparatus of claim **13**, wherein the means for determining the application type determines the application type based at least in part on an application associated with the media stream.

20. The apparatus of claim **13**, wherein the application type of the media stream is one of a gaming application type, an interactive computing application type, or a media viewing application type.

21. The apparatus of claim **13**, wherein the transport stream comprises a Moving Picture Experts Group (MPEG) transport stream (MPEG-TS).

22. The apparatus of claim **13**, wherein the time reference values comprise one or more of a presentation time stamp (PTS) or a decode time stamp (DTS), or a combination thereof.

23. The apparatus of claim **13**, wherein the shared clock reference comprises a program clock reference (PCR) synchronized at the sink device.

24. The apparatus of claim **13**, further comprising:
means for receiving, by an application programming interface of the source device, a call from an application running on the source device for establishing a streaming display connection with the sink device, and

wherein the means for determining the application type of the media stream determines the application type based on the received call.

25. A device for dynamic control of sink device buffering by a source device, comprising:

a processor; and

a memory in electronic communication with the processor, the memory embodying instructions, the instructions being executable by the processor to:

determine an application type of a media stream for transmission to a sink device;

determine at least one of an off-channel concurrency latency based at least in part on a concurrent connection configuration of the source device or a scanning latency using a channel scanning configuration of the source device;

determine, based at least in part on the application type and at least one of the off-channel concurrency latency or the scanning latency, a buffer size used by the sink device for buffering of a transport stream used for encapsulation of the media stream;

encode frames of the media stream with time reference values relative to a shared clock reference using the determined buffer size; and

encapsulate the encoded frames in the transport stream.

26. The device of claim **25**, the memory embodying instructions being executable by the processor to:

determine the off-channel concurrency latency based at least in part on the concurrent connection configuration of the source device; and

determine the buffer size further based on the determined off-channel concurrency latency.

27. The device of claim **25**, the memory embodying instructions being executable by the processor to:

determine the scanning latency using the channel scanning configuration of the source device; and

determine the buffer size further based on the determined scanning latency.

28. The device of claim **25**, the memory further embodying instructions being executable by the processor to:

transmit the transport stream to the sink device over a wireless local area network connection.

29. The device of claim **28**, the memory further embodying instructions being executable by the processor to:

display the media stream at the source device concurrently with encoding of the media stream for transmission to the sink device.

30. The device of claim **28**, the memory further embodying instructions being executable by the processor to:

transmit time values of the shared clock reference at periodic intervals in the transport stream.

31. The device of claim **25**, the memory further embodying instructions being executable by the processor to:

determine the application type based at least in part on an application associated with the media stream.

32. The device of claim **25**, wherein the application type of the media stream is one of a gaming application type, an interactive computing application type, or a media viewing application type.

33. The device of claim **25**, wherein the transport stream comprises a Moving Picture Experts Group (MPEG) transport stream (MPEG-TS).

34. The device of claim **25**, wherein the time reference values comprise one or more of a presentation time stamp (PTS) or a decode time stamp (DTS), or a combination thereof.

35. The device of claim **25**, wherein the shared clock reference comprises a program clock reference (PCR) synchronized at the sink device.

36. The device of claim **25**, the memory further embodying instructions being executable by the processor to:

receive, by an application programming interface of the source device, a call from an application running on the source device for establishing a streaming display connection with the sink device; and

determine the application type of the media stream based on the received call.

37. A non-transitory computer program product for dynamic control of sink device buffering by a source device, comprising:

a non-transitory computer-readable medium, comprising code for:

determining an application type of a media stream for transmission to a sink device;

determining at least one of an off-channel concurrency latency based at least in part on a concurrent connection configuration of the source device or a scanning latency using a channel scanning configuration of the source device;

determining, based at least in part on the application type, and at least one of the off-channel concurrency latency or the scanning latency, a buffer size used by the sink device for buffering of a transport stream used for encapsulation of the media stream;

encoding frames of the media stream with time reference values relative to a shared clock reference using the determined buffer size; and

encapsulating the encoded frames in the transport stream.

38. The non-transitory computer program product of claim **37**, wherein the non-transitory computer-readable medium comprises code for:

determining the off-channel concurrency latency based at least in part on the concurrent connection configuration of the source device; and

determining the buffer size further based on the determined off-channel concurrency latency.

39. The non-transitory computer program product of claim **37**, wherein the non-transitory computer-readable medium comprises code for:

determining the scanning latency based at least in part on the channel scanning configuration of the source device; and

determining the buffer size further based on the determined scanning latency.

40. The non-transitory computer program product of claim **37**, wherein the non-transitory computer-readable medium further comprises code for:

transmitting the transport stream to the sink device over a wireless local area network connection.

41. The non-transitory computer program product of claim **40**, wherein the non-transitory computer-readable medium further comprises code for:

displaying the media stream at the source device concurrently with encoding of the media stream for transmission to the sink device.

42. The non-transitory computer program product of claim **40**, wherein the non-transitory computer-readable medium further comprises code for: transmitting time values of the shared clock reference at periodic intervals in the transport stream.

43. The non-transitory computer program product of claim **37**, wherein the non-transitory computer-readable medium further comprises code for:

determining the application type based at least in part on an application associated with the media stream.

44. The non-transitory computer program product of claim **37**, wherein the application type of the media stream is one of a gaming application type, an interactive computing application type, or a media viewing application type.

45. The non-transitory computer program product of claim **37**, wherein the transport stream comprises a Moving Picture Experts Group (MPEG) transport stream (MPEG-TS).

46. The non-transitory computer program product of claim **37**, wherein the time reference values comprise one or more of a presentation time stamp (PTS) or a decode time stamp (DTS), or a combination thereof.

47. The non-transitory computer program product of claim **37**, wherein the shared clock reference comprises a program clock reference (PCR) synchronized at the sink device.

48. The non-transitory computer program product of claim **37**, wherein the non-transitory computer-readable medium further comprises code for:

receiving, by an application programming interface of the source device, a call from an application running on the source device for establishing a streaming display connection with the sink device; and

determining the application type of the media stream based on the received call.

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