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(54) METHOD AND APPARATUS FOR ELECTRONIC DEVICE COMMUNICATION

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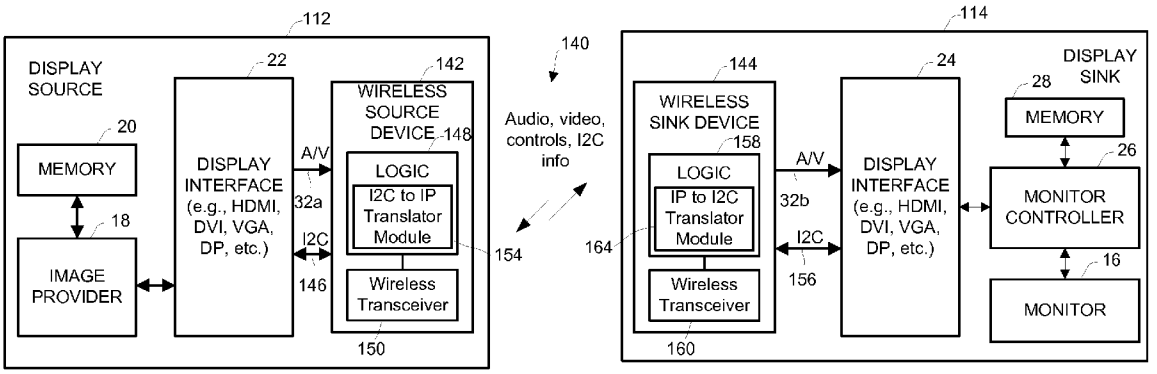
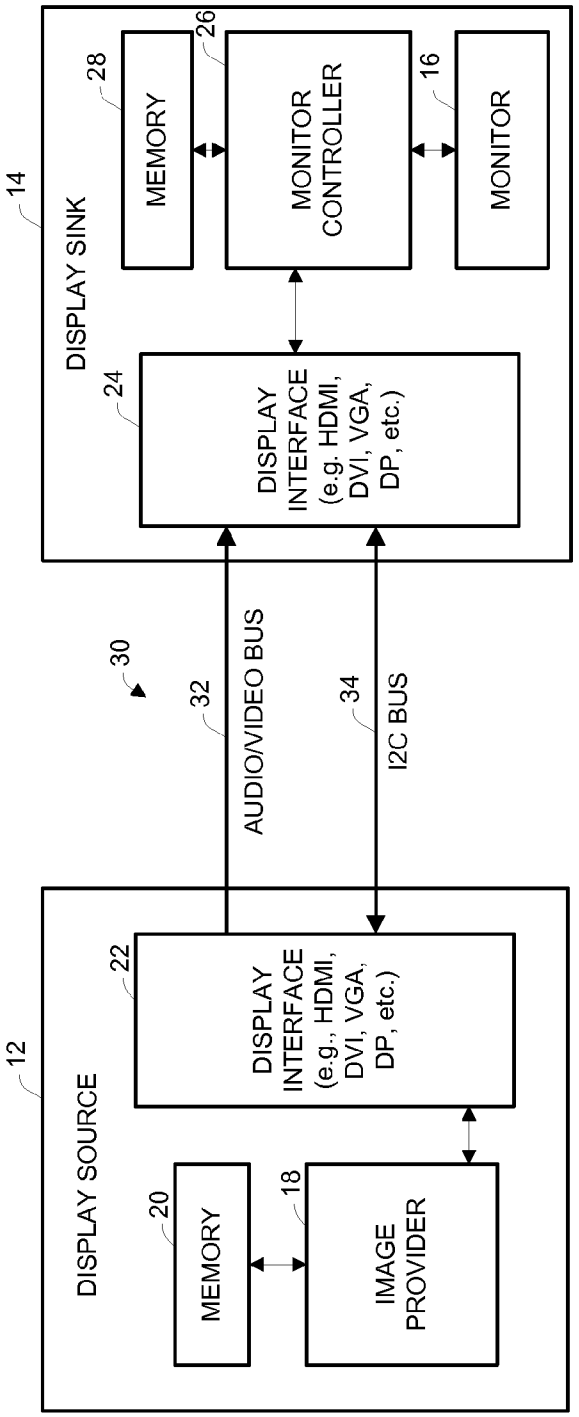
(52) **U.S. Cl.**
USPC **725/109**

(57) **ABSTRACT**

The present disclosure relates to a method and apparatus for electronic device communication. A method includes translating monitor control commands to an internet protocol (IP) format to produce IP formatted monitor control commands, and communicating the IP formatted monitor control commands to an IP port dedicated for communicating IP formatted monitor control commands.





10

FIG. 1
(PRIOR ART)

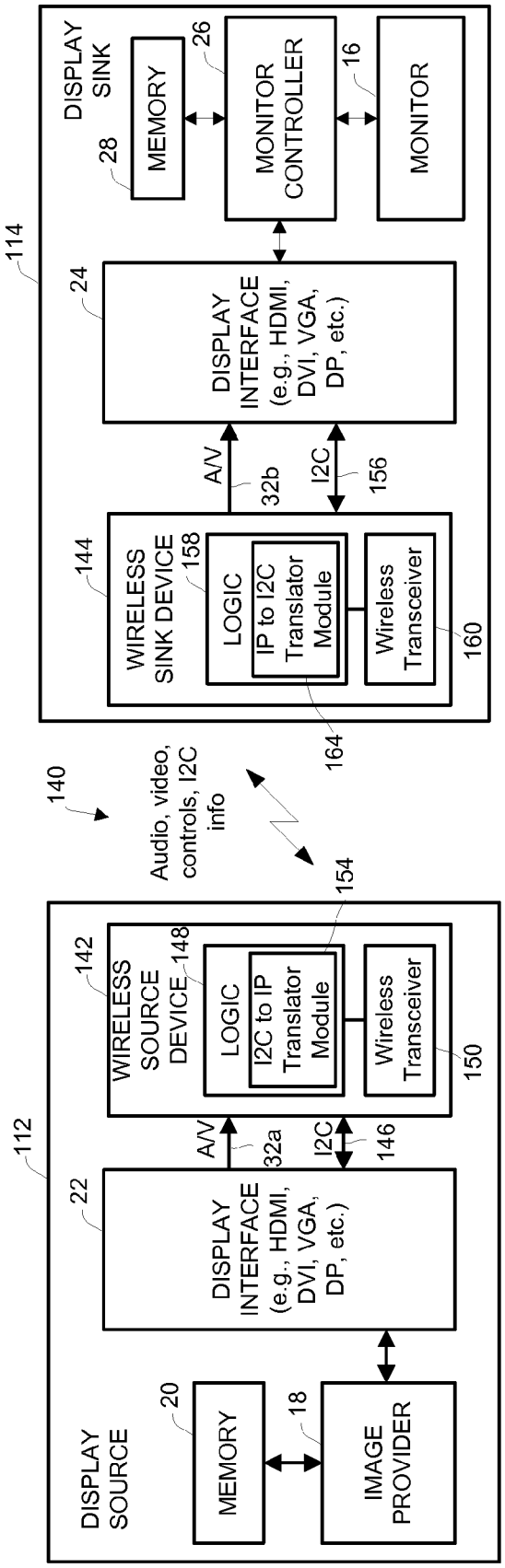

DISPLAY SOURCE
112
MEMORY
20
IMAGE PROVIDER
18
DISPLAY INTERFACE (e.g., HDMI, DVI, VGA, DP, etc.)
22
A/V
32a
I2C
146
WIRELESS SOURCE DEVICE
142
LOGIC
148
I2C to IP Translator Module
Wireless Transceiver
150
154
140
Audio, video, controls, I2C info
164
WIRELESS SINK DEVICE
144
LOGIC
158
IP to I2C Translator Module
Wireless Transceiver
160
A/V
32b
I2C
156
DISPLAY INTERFACE (e.g., HDMI, DVI, VGA, DP, etc.)
24
114
DISPLAY SINK
MEMORY
28
MONITOR CONTROLLER
26
MONITOR
16
100

FIG. 2

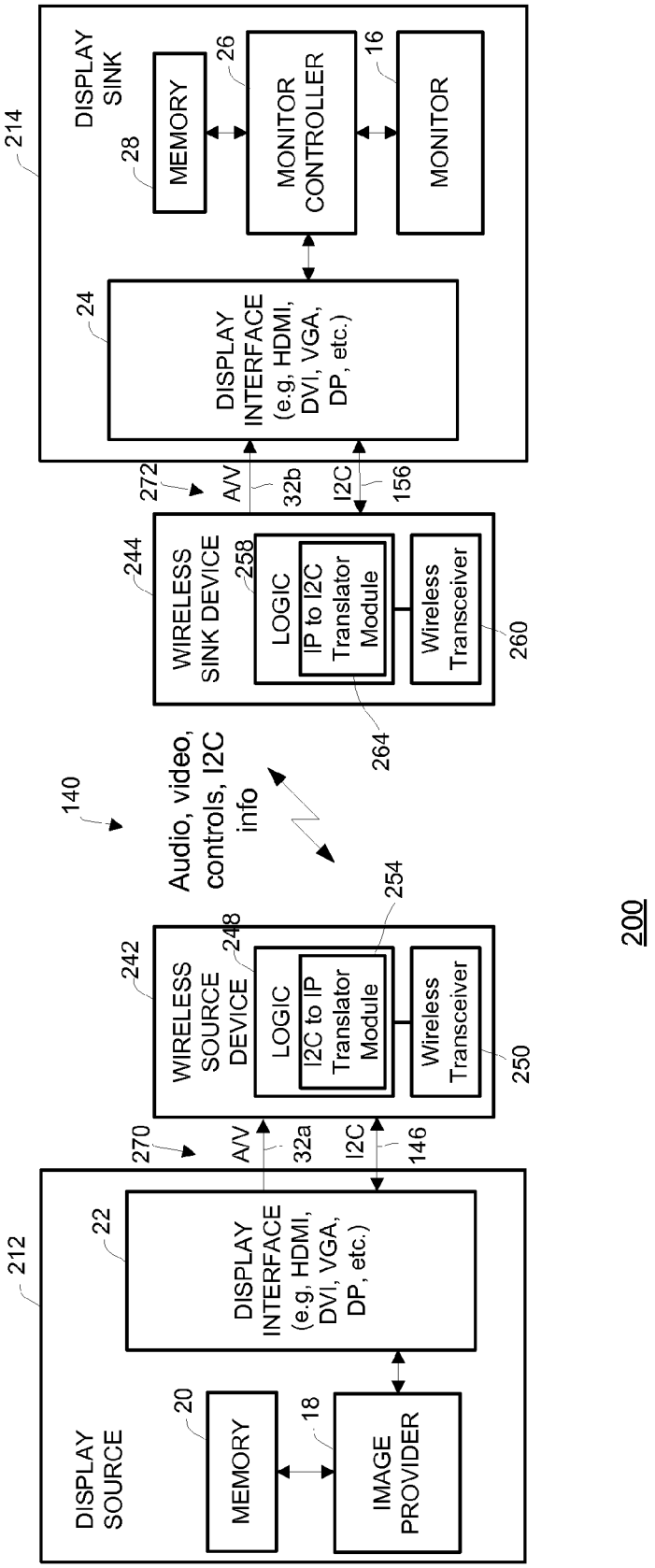

DISPLAY SOURCE
212
MEMORY
20
IMAGE PROVIDER
18
DISPLAY INTERFACE (e.g, HDMI, DVI, VGA, DP, etc.)
22
270
A/V
32a
I2C
146
WIRELESS SOURCE DEVICE
242
LOGIC
248
I2C to IP Translator Module
254
Wireless Transceiver
250
140
Audio, video, controls, I2C info
WIRELESS SINK DEVICE
244
LOGIC
258
IP to I2C Translator Module
264
Wireless Transceiver
260
272
A/V
32b
I2C
156
DISPLAY SINK
214
MEMORY
28
MONITOR CONTROLLER
26
MONITOR
16
DISPLAY INTERFACE (e.g, HDMI, DVI, VGA, DP, etc.)
24
200

FIG. 3

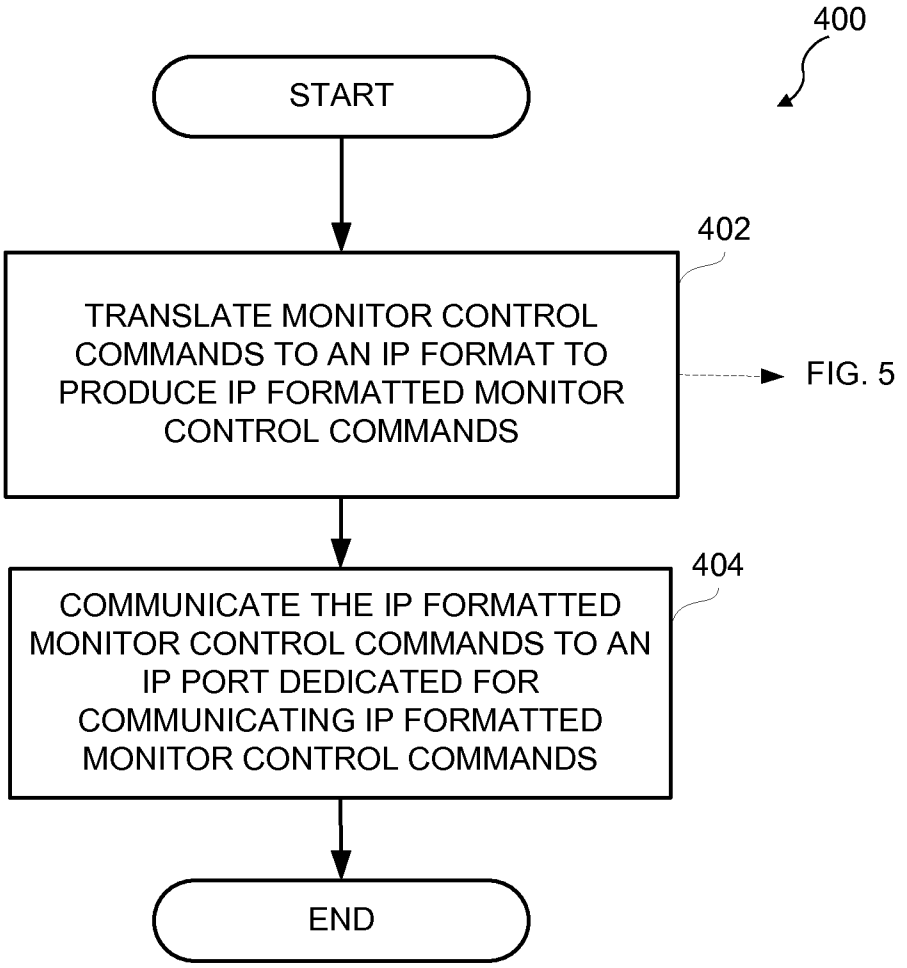

400
START
402
TRANSLATE MONITOR CONTROL COMMANDS TO AN IP FORMAT TO PRODUCE IP FORMATTED MONITOR CONTROL COMMANDS
FIG. 5
404
COMMUNICATE THE IP FORMATTED MONITOR CONTROL COMMANDS TO AN IP PORT DEDICATED FOR COMMUNICATING IP FORMATTED MONITOR CONTROL COMMANDS
END

FIG. 4

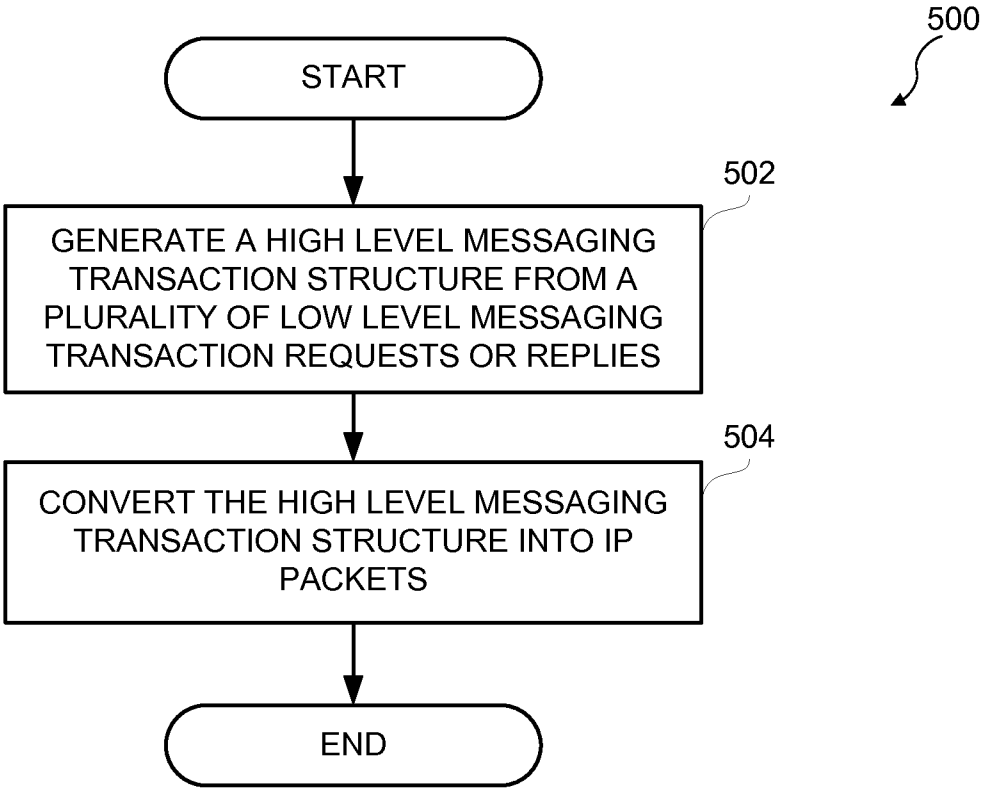

500
START
502
GENERATE A HIGH LEVEL MESSAGING TRANSACTION STRUCTURE FROM A PLURALITY OF LOW LEVEL MESSAGING TRANSACTION REQUESTS OR REPLIES
504
CONVERT THE HIGH LEVEL MESSAGING TRANSACTION STRUCTURE INTO IP PACKETS
END

FIG. 5

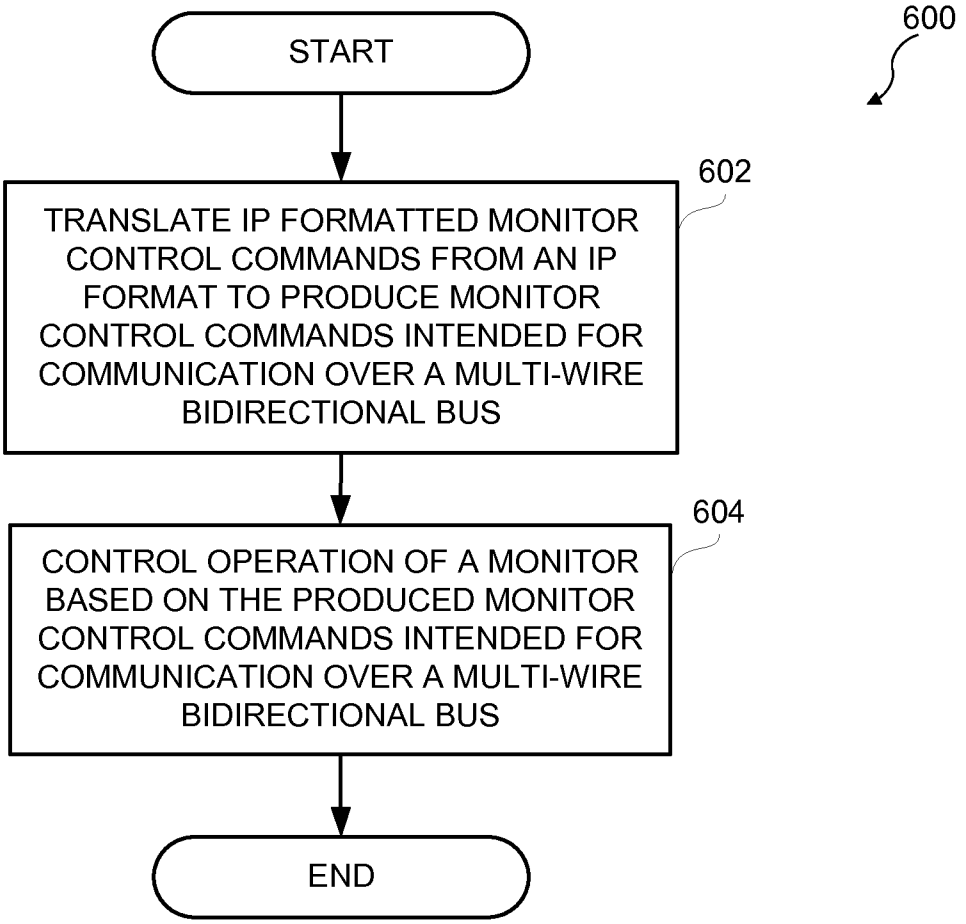

600
START
602
TRANSLATE IP FORMATTED MONITOR CONTROL COMMANDS FROM AN IP FORMAT TO PRODUCE MONITOR CONTROL COMMANDS INTENDED FOR COMMUNICATION OVER A MULTI-WIRE BIDIRECTIONAL BUS
604
CONTROL OPERATION OF A MONITOR BASED ON THE PRODUCED MONITOR CONTROL COMMANDS INTENDED FOR COMMUNICATION OVER A MULTI-WIRE BIDIRECTIONAL BUS
END

FIG. 6

700 Remote I2C Read Request Structure

FIELD	SIZE (OCTETS)	DESCRIPTION
REQUEST IDENTIFIER	1	THIS FIELD SHOULD BE SET TO 0X00 TO INDICATE REMOTE_I2C_READ_REQUEST.
NUMBER_OF_I2C_WRITE_TRANSACTIONS	1	THE TOTAL NUMBER OF I2C WRITE TRANSACTIONS TO BE SENT IN THIS MESSAGE TRANSACTION.
702 FOR (I=0; I <NUMBER_OF_I2C_WRITE_TRANSACTIONS - 1; I++) {		
WRITE_I2C_DEVICE_IDENTIFIER[I]	1	THE I2C DEVICE IDENTIFIER TO RECEIVE THE WRITE REQUEST
NUMBER_OF_BYTES_TO-WRITE[I]	1	THE NUMBER OF DATA BYTES TO WRITE TO THE I2C DEVICE
FOR (J=0; J < NUMBER_OF_BYTES_TO_WRITE; J++) I2C_DATA_TO_WRITE[I][J]	1	THE I2C WRITE DATA FOR THE WRITE DEVICE. TOTAL NUMBER OF BYTES TO WRITE FOR EACH WRITE TRANSACTION IS EQUAL TO NUMBER_OF_BYTES_TO_WRITE[I]
NO_STOP_BIT[I]	1	WHEN SET TO A 0X01, A STOP BIT IS NOT SENT AT THE END OF THE I2C TRANSACTION; OTHERWISE WHEN SET TO A 0X00, A STOP WILL BE GENERATED AT THE END OF THE I2C TRANSACTION.
I2C_TRANSACTION_DELAY[I] }	1	THE AMOUNT OF DELAY TO INSERT BETWEEN THIS AND THE NEXT I2C TRANSACTION. THE DELAY UNIT IS 10MS. THE DELAY RANGE IS 0 TO 150 MS.
READ_I2C_DEVICE_IDENTIFIER	1	THE I2C DEVICE IDENTIFIER TO RECEIVE THE READ REQUEST.
NUMBER_OF_BYTES_TO_READ	1	THE NUMBER OF DATA BYTES REQUESTED TO READ FROM THE I2C DEVICE.

720 Remote I2C Write Request Structure

FIELD	SIZE (OCTETS)	DESCRIPTION
REQUEST IDENTIFIER	1	FIELD SET TO 0X01 TO INDICATE REMOTE_I2C_WRITE_REQUEST.
WRITE_I2C_DEVICE_IDENTIFIER	1	THE I2C DEVICE IDENTIFIER TO RECEIVE THE WRITE REQUEST.
722 NUMBER_OF_BYTES_TO_WRITE	1	THE NUMBER OF DATA BYTES TO WRITE TO THE I2C DEVICE.
FOR (J=0; J < NUMBER_OF_BYTES_TO_WRITE; J++) I2C_DATA_TO_WRITE[I]	1	THE I2C WRITE DATA FOR THE WRITE DEVICE TOTAL NUMBER OF BYTES TO WRITE IS EQUAL TO NUMBER_OF_BYTES_TO_WRITE.

FIG. 7.1

730

Remote I2C Read Reply Acknowledge Success

FIELD	SIZE (OCTETS)	DESCRIPTION
REPLY IDENTIFIER	1	FIELD SET TO 0X00 TO INDICATE REMOTE_I2C_READ_REPLY_ACK.
NUMBER_OF_BYTES_TO_READ	1	THE NUMBER OF DATA BYTES READ FROM THE I2C DEVICE.
FOR (I=0; I < NUMBER_OF_BYTES_READ; I++) I2C_DEVICE_BYTE_READ	1	A DATA BYTE READ FROM THE I2C DEVICE

740

Remote I2C Read Reply Acknowledge Failure

FIELD	SIZE (OCTETS)	DESCRIPTION
REPLY IDENTIFIER	1	FIELD SET TO 0X80 TO INDICATE REMOTE_I2C_READ_REPLY_NAK.

750

Remote I2C Write Reply Acknowledge Success

FIELD	SIZE (OCTETS)	DESCRIPTION
REPLY IDENTIFIER	1	FIELD SET TO 0X01 TO INDICATE REMOTE_I2C_WRITE_REPLY_ACK.

760

Remote I2C Write Reply Acknowledge Failure

FIELD	SIZE (OCTETS)	DESCRIPTION
REPLY IDENTIFIER	1	FIELD SET TO 0X81 TO INDICATE REMOTE_I2C_WRITE_REPLY_NAK.

FIG. 7.2

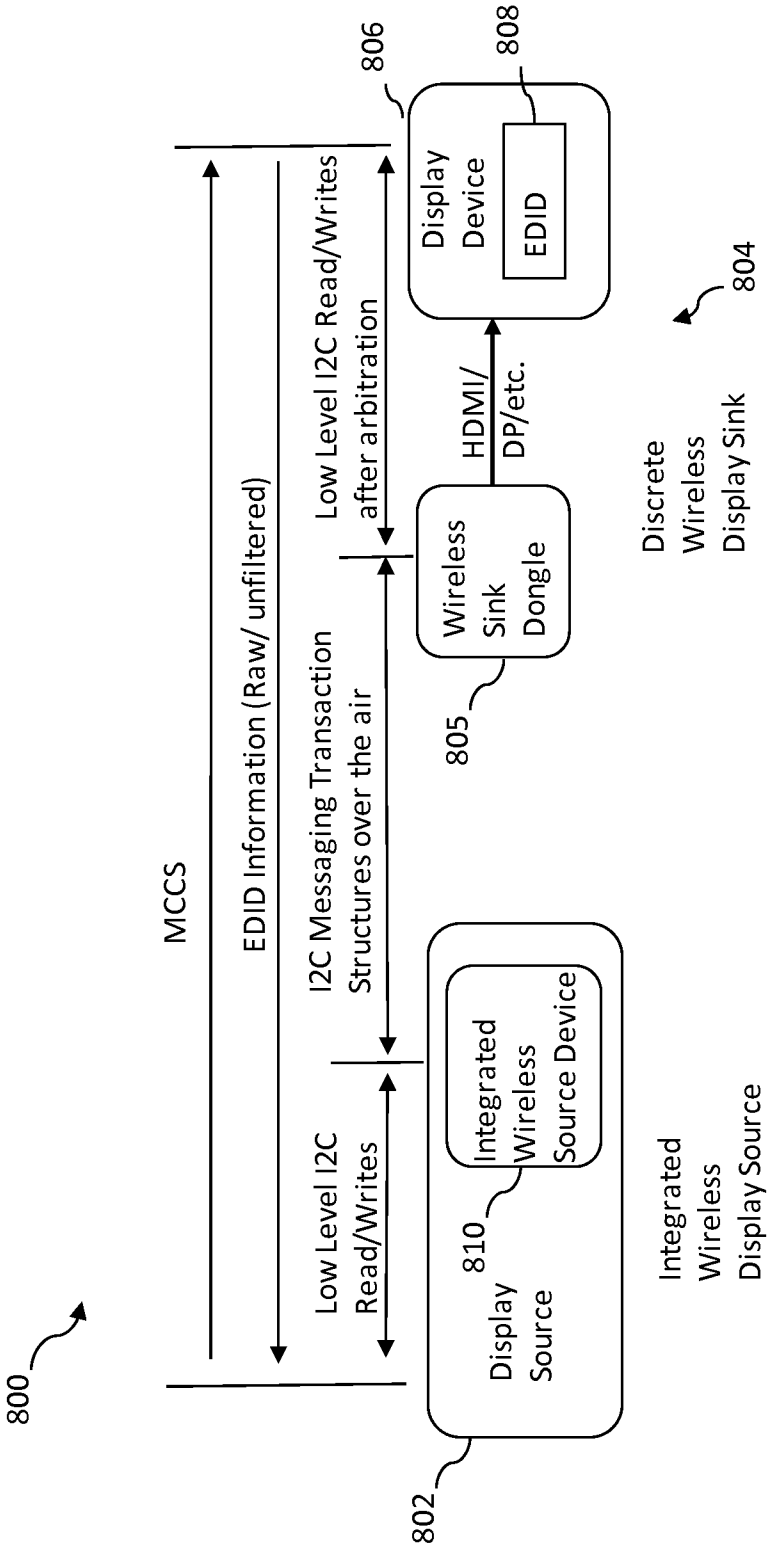

800
MCCS
EDID Information (Raw/ unfiltered)
Low Level I2C Read/Writes
I2C Messaging Transaction
Structures over the air
Low Level I2C Read/Writes
after arbitration
Display
Source
Integrated
Wireless
Source Device
810
802
Integrated
Wireless
Display Source
Wireless
Sink
Dongle
805
HDMI/
DP/etc.
Display
Device
EDID
806
808
804
Discrete
Wireless
Display Sink

FIG. 8

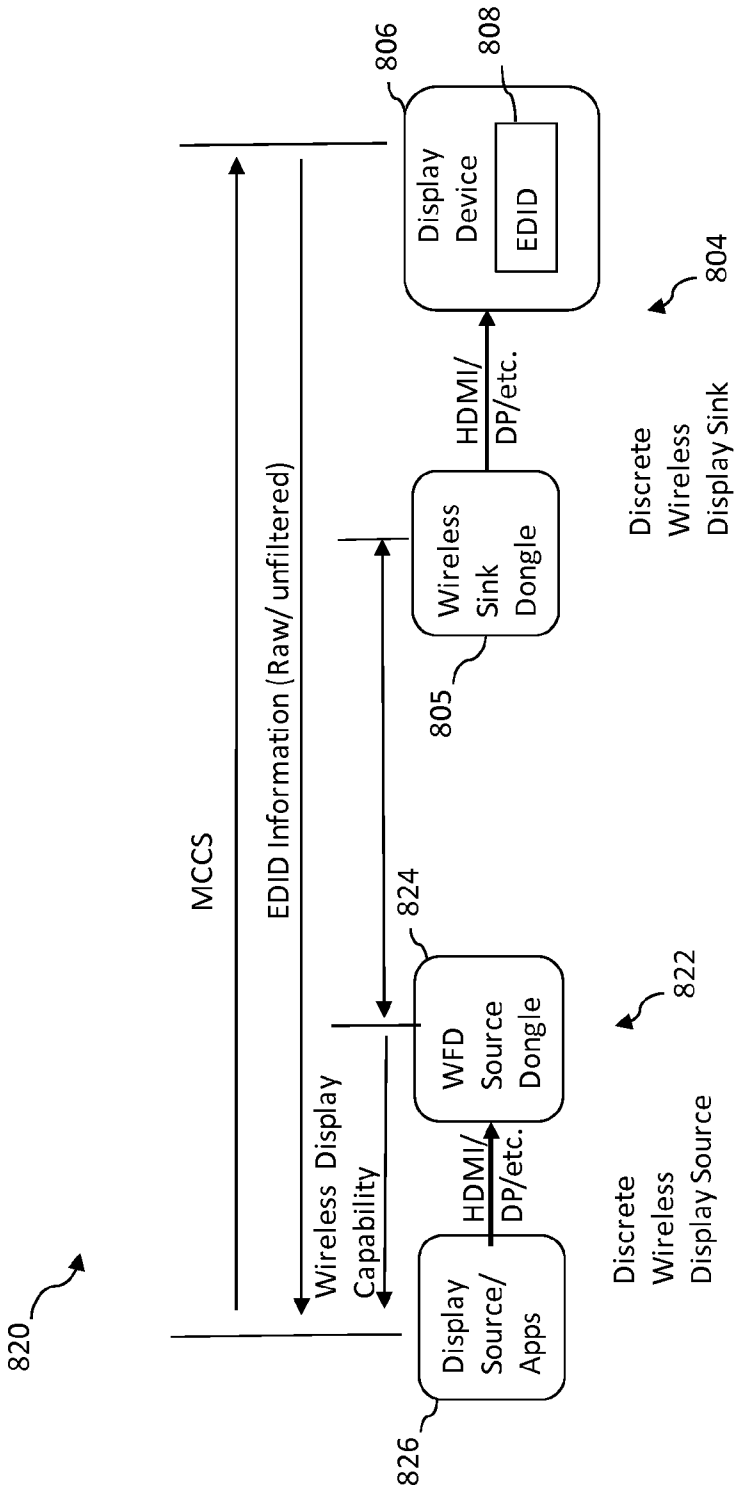

820
MCCS
EDID Information (Raw/ unfiltered)
Wireless Display Capability
Display Source/ Apps
826
HDMI/ DP/etc.
WFD Source Dongle
824
822
Discrete Wireless Display Source
Wireless Sink Dongle
805
HDMI/ DP/etc.
Display Device
EDID
806
808
804
Discrete Wireless Display Sink

FIG. 9

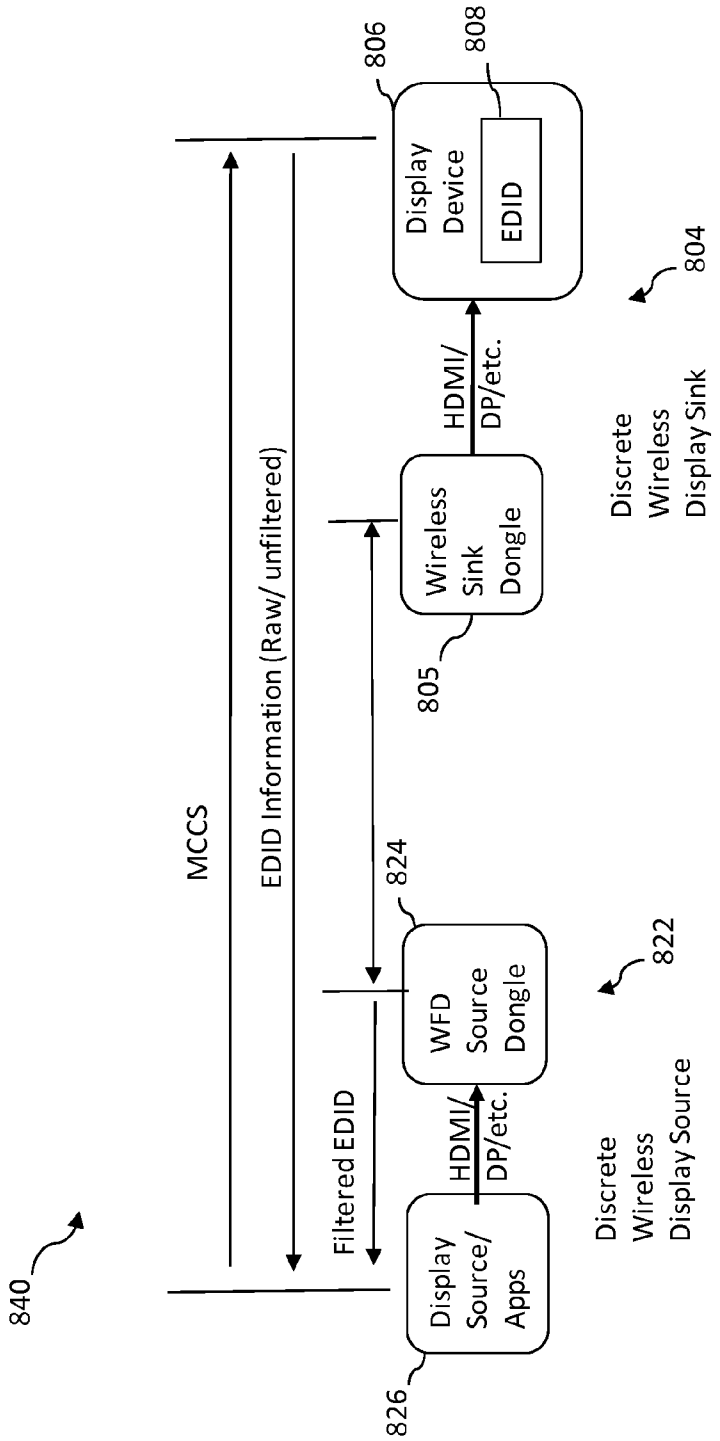

840
MCCS
EDID Information (Raw/ unfiltered)
Filtered EDID
Display Source/ Apps
826
HDMI/ DP/etc.
WFD Source Dongle
824
822
Discrete Wireless Display Source
Wireless Sink Dongle
805
HDMI/ DP/etc.
Display Device
EDID
806
808
804
Discrete Wireless Display Sink

FIG. 10

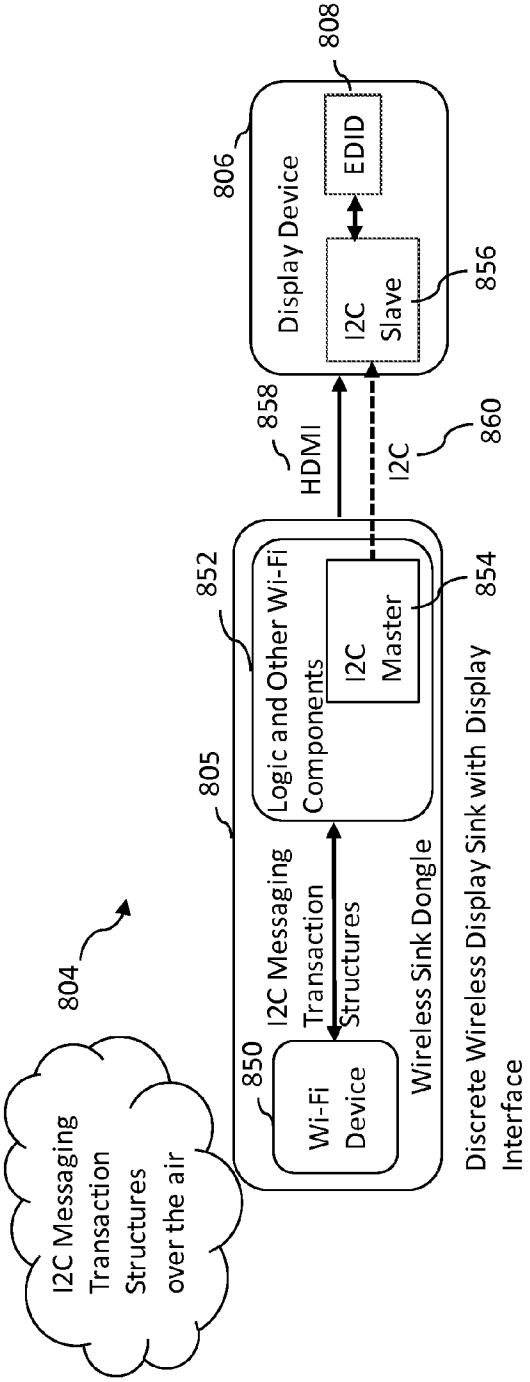

I2C Messaging Transaction Structures over the air
804
805
850
Wi-Fi Device
I2C Messaging Transaction Structures
852
Logic and Other Wi-Fi Components
854
I2C Master
Wireless Sink Dongle
Discrete Wireless Display Sink with Display Interface
858
HDMI
860
I2C
806
Display Device
808
EDID
856
I2C Slave

FIG. 11

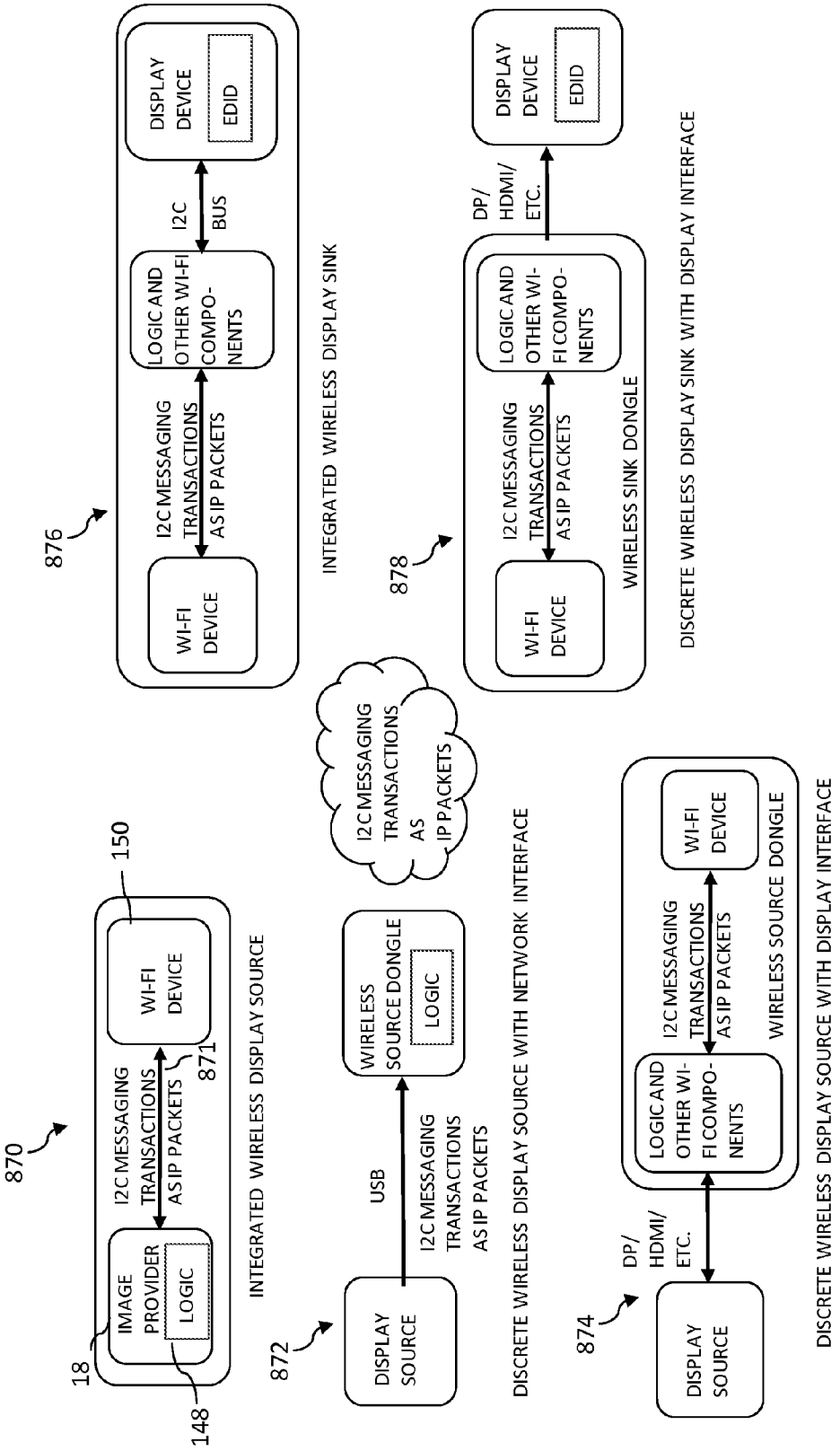

870
IMAGE PROVIDER
LOGIC
18
148
I2C MESSAGING TRANSACTIONS AS IP PACKETS
WI-FI DEVICE
150
871
INTEGRATED WIRELESS DISPLAY SOURCE
876
WI-FI DEVICE
I2C MESSAGING TRANSACTIONS AS IP PACKETS
LOGIC AND OTHER WI-FI COMPO-NENTS
I2C BUS
DISPLAY DEVICE
EDID
INTEGRATED WIRELESS DISPLAY SINK
872
DISPLAY SOURCE
USB
I2C MESSAGING TRANSACTIONS AS IP PACKETS
WIRELESS SOURCE DONGLE
LOGIC
DISCRETE WIRELESS DISPLAY SOURCE WITH NETWORK INTERFACE
I2C MESSAGING TRANSACTIONS AS IP PACKETS
878
WI-FI DEVICE
I2C MESSAGING TRANSACTIONS AS IP PACKETS
LOGIC AND OTHER WI-FI COMPO-NENTS
WIRELESS SINK DONGLE
DP/ HDMI/ ETC.
DISPLAY DEVICE
EDID
DISCRETE WIRELESS DISPLAY SINK WITH DISPLAY INTERFACE
874
DISPLAY SOURCE
DP/ HDMI/ ETC.
LOGIC AND OTHER WI-FI COMPO-NENTS
I2C MESSAGING TRANSACTIONS AS IP PACKETS
WI-FI DEVICE
WIRELESS SOURCE DONGLE
DISCRETE WIRELESS DISPLAY SOURCE WITH DISPLAY INTERFACE

FIG. 12

METHOD AND APPARATUS FOR ELECTRONIC DEVICE COMMUNICATION

FIELD OF THE DISCLOSURE

[0001] The present disclosure is generally related to the field of image display systems, and more particularly to methods and systems for communication between a display source and a display sink over a communication link.

BACKGROUND

[0002] Conventional display systems typically include a wired connection between a display source (e.g, computer, DVD/Blu-ray device, cell phone, set-top box, etc.) and a display sink (e.g., a device that receives data for producing an image such as but not limited to a computer monitor, television, projector, hub, etc.) for communicating multimedia data and other display controls and capability data. Wired communication links or interfaces between the display source and the display sink may include video graphics array (VGA), digital video interface (DVI), high definition multimedia interface (HDMI), DisplayPort (DP), and other wired communication interfaces. The communication interface may include an Inter-Integrated Circuit (I2C) bus for communicating monitor control commands and monitor capability information between the display source and the display sink. The I2C bus is a multi-wire (typically including a data wire and a clock wire), bidirectional communication bus that provides for serial communication between connected components.

[0003] Referring to FIG. **1**, an exemplary known display system **10** is illustrated that utilizes an I2C bus for communicating monitor control commands and monitor capability data. Display system **10** includes a display source **12**, such as a computer (e.g., laptop, desktop, tablet, etc.), cell phone, DVD/Blueray device, set-top box, etc., that is operative to provide audio/video data or other multi-media data to a display sink **14** for display on a monitor **16** (e.g., display, screen, etc.) of display sink **14**. Display sink **14** may include a computer monitor device, a television, a video/image projector, or any other suitable display sink **14** operative to display image data (e.g., video, graphics, etc.) and/or to convert audio data into sound. The connections lines between components of display system **10** illustrated in FIG. **1** represent physical electrical connections (e.g., conductors, wires) between the components.

[0004] Display source **12** includes an image provider **18** that is operative to generate or decode audio and image (video or graphics) data. Image provider **18** may include a graphics processor (e.g. one or more GPU cores), decoder, or other control unit operative to generate or decode multimedia data, such as audio, video, and other image data. In some embodiments, image provider **18** further includes a main processor (e.g., one or more CPU cores) that includes an operating system operative to issue control commands to display sink **14** and to request data from display sink **14**. In one embodiment, a graphics processor and a main or central processor are provided in an integrated circuit of image provider **18**, although processors and logic components of image provider **18** may comprise separate devices. Display source **12** includes a memory **20**, internal or external to image provider **18**, containing data, such as image or control data, accessible by image provider **18**. Memory **20** may include software or firmware with program instructions that when executed by a processor of image provider **18** performs one or more computing tasks. Memory **20** may also include image data used by image provider **18** to provide video or graphics data.

[0005] Display sink **14** illustratively includes a monitor controller **26** operatively coupled to monitor **16** and to a memory **28**. Monitor controller **26**, which may include a processor or other suitable logic that is operative to process multimedia data, such as audio data and video and/or graphics image data, received from image provider **18** of display source **12** and to provide the processed data to monitor **16** for display on monitor **16**. As described herein, monitor controller **26** is also operative to control monitor **16** based on control commands received from display source **12** and to provide monitor capability data to display source **12**. Memory **28** may be internal or external to monitor controller **26** and stores data, such as image or control data, accessible by monitor controller **26** for controlling monitor **16**. Memory **20** may further include software or firmware with program instructions that when executed by a processor of monitor controller **26** performs one or more computing tasks associated with monitor **16**. Memory may be any suitable memory including but not limited to RAM, ROM, EEPROM, DDRAM, optical memory, distributed memory in differing devices such as web servers or any suitable non-transitory memory.

[0006] A display interface **22** of display source **12** provides a communication interface between image provider **18** of display source **12** and display sink **14**. Similarly, a display interface **24** of display sink **14** provides a communication interface between monitor controller **18** of display sink **14** and display source **12**. Display interfaces **22**, **24** may include a video graphics array (VGA), digital video interface (DVI), high definition multimedia interface (HDMI), DisplayPort (DP), or other communication interface. A communication cable **30** is coupled from display interface **22** to display interface **24**. Communication cable **30** includes a connector cable or wire, or other suitable wired connector, that is compatible with the communication interface (e.g., VGA, DVI, HDMI, DP, etc.) of display interfaces **22**, **24**. Communication cable **30** illustratively includes an audio/video bus **32** for communicating audio, video, other image data, and various controls from display source **12** to display sink **14**. Audio/video bus **32** is illustratively unidirectional from display source **12** to display sink **14**. In the illustrated embodiment, communication cable **30** further includes an I2C bus **34** for communicating monitor control commands and monitor capability information between display source **12** and display sink **14**. Audio/video bus **32** and I2C bus **34** are illustratively provided in a single communication cable **30**. In one embodiment with a DisplayPort interface, communication cable **30** includes a pair of auxiliary (AUX) wires rather than an I2C bus **34** for communicating the monitor control commands and monitor capability information between display interfaces **22**, **24**.

[0007] I2C bus **34** communicates monitor control commands and monitor capability information between display source **12** and display sink **14**. Capability information may include extended display identification data (EDID) or other suitable data representing the display capabilities of monitor **16**. EDID includes a data structure provided at display sink **14**, such as at memory **28** accessible by monitor controller **26**, that describes to display source **12** the display and operational capabilities of monitor **16**. Exemplary capability data includes graphics modes, frame rate, display size and aspect ratio, resolution, color capabilities, and other suitable monitor capability information. Image provider **18** performs mul-

tiple functions or operations based on the EDID structure. Upon reading the EDID structure, image provider **18** is configured to identify the type and capabilities of monitor **16** and to tailor the audio/video data (or other image data) to conform to the capabilities of the monitor **16**. For example, image provider **18** may scale the video or image content provided to display sink **14** based on whether monitor **16** has enabled overscan functionality, as determined from the display capability information in the EDID structure. In another example, image provider **18** performs color management based on the display gamut and related information of monitor **16** provided in the EDID structure. Other operations may be performed by image provider **18** based on EDID information and other control/capability information.

[0008] Monitor control commands communicated over I2C bus **34** may include Monitor Command and Controls Set (MCCS) commands or other suitable monitor control commands provided from display source **12** to display sink **14** for controlling the display properties of monitor **16**. Each MCCS command includes various data parameters and command attributes operative to control the display properties of monitor **16**. MCCS commands are operative to restore factory defaults (e.g., color, geometry, brightness/contrast, and other presets/defaults) of the monitor **16**, to control color temperature, hue, and saturation, to adjust display geometry (e.g., parallelogram, pincushion, etc.), and to control image display parameters. Exemplary image display parameters include display orientation, zoom, brightness, contrast, gamma, focus, backlight control, white point, and other image parameters. The I2C bus **34** may be used to transfer other display setup information. In one embodiment, monitor display sink **14** provides reply data or controls over I2C bus **34** to display source **12** in response to monitor control commands.

[0009] In one embodiment, the I2C bus **34** utilizes Display Data Channel and/or Command Interface (DDC/CI) communication protocol to communicate EDID information, MCCS commands, and other data or monitor control commands between display source **12** and display sink **14**. DDC/CI protocol may provide a "plug and play" environment such that display source **12** and display sink **14** are able to communicate upon connection to the I2C bus **34**.

[0010] Monitor controller **26** controls monitor **16** based on the monitor control commands from display source **12**. For example, upon image provider **18** issuing an MCCS command or other monitor control command to display sink **14** via the IC2 bus **34**, the monitor controller **26** displays the video or other image data, or processes audio data, in accordance with the issued commands. Similarly, upon image provider **18** issuing an EDID request via the IC2 bus **34**, monitor controller **26** provides the EDID information of monitor **16** to display source **12** via the I2C bus **34**.

[0011] The I2C bus **34** is configured to communicate low-level messaging transactions (e.g., single byte messages) between image provider **18** of display source **12** and monitor controller **26** of display sink **14**. These low-level messages may include read or write commands, such as read/write replies and requests. In one embodiment, I2C bus **34** includes two wires, i.e., a data wire and a clock wire, that provides for serial communication between display source **12** and display sink **14**. For example, in one embodiment, information from the EDID structure, MCCS commands, and other display data or monitor control commands are transmitted over I2C bus **34** a single byte at a time. As such, a monitor control command, for example, may include a plurality of low level (e.g., single byte) messaging transaction requests. Another suitable multi-wired, bidirectional communication bus may be provided as an alternative to I2C bus **34** for handling the communication of low-level messaging transactions containing monitor control and capability information.

[0012] Some display systems **10** are operative to provide audio/video data to the display sink **14** over a computer networking protocol, such as an internet protocol (IP) format including Transmission Control Protocol/Internet Protocol (TCP/IP) or User Datagram Protocol (UDP), for example. Rather than being directly connected with a communication interface **30** such as VGA, DVI, HDMI, DP, or other wired interface, the display source **12** and display sink **14** are connected via an IP link to remotely communicate with each other over a wired or wireless IP network. However, such IP communication links do not support the communication of I2C read/write messaging transactions (e.g., MCCS commands, DDC/IC protocol, EDID information, etc.) between the display source **12** and the display sink **14**. Without a mechanism to enable the communication of remote I2C read/write messaging transactions over an IP interface, some or all operations performed by the image provider **18** based on the monitor control commands and capability data previously communicated via I2C bus **34** may be either compromised or performed at the display sink **14**. However, performance of such operations by the display sink **14** results in increased complexity of the display sink **14** and increased likelihood of compatibility issues between the display source **12** and the display sink **14**. Further, the processor(s) and/or control logic of the image provider **18** of display source **12** is typically much more flexible in operation and is better adapted to handle changes in the monitor control/capabilities.

[0013] Therefore, a need exists for methods and systems to communicate monitor control commands and other monitor data between a display source and a display sink using a network protocol communication interface, such as an internet protocol (IP) communication interface.

SUMMARY OF EMBODIMENTS OF THE DISCLOSURE

[0014] In an exemplary embodiment of the present disclosure, a method carried out by an electronic device is provided. The method includes translating monitor control commands to an network protocol format to produce network protocol formatted monitor control commands. The method further includes communicating the network protocol formatted monitor control commands to a network protocol port dedicated for communicating network protocol formatted monitor control commands.

[0015] Among other advantages, the method and apparatus allows for communication of monitor control commands, monitor capability information, and other monitor data between a display source and a display sink using a network protocol (e.g., internet protocol (IP)) communication interface, such as a wireless interface. The enabled communication of monitor control commands, capability data, and other data intended for communication over an I2C bus, for example, allows a display source communicating over an IP communication interface to control the display operations and the display features and capabilities of the display system, as described herein. Other advantages will be recognized by those of ordinary skill in the art.

[0016] In one example, the translating the monitor control commands to a network protocol format to produce network

protocol formatted monitor control commands includes translating monitor control commands intended for communication over a multi-wire bidirectional bus. In another example, the communicating the network protocol formatted monitor control commands to the dedicated network protocol port includes identifying a network protocol port of a destination device, such as a display sink, and dedicating the identified network protocol port for communicating network protocol formatted monitor control commands. In yet another example, the translating the monitor control commands to a network protocol format to produce network protocol formatted monitor control commands includes generating a high level messaging transaction structure from a plurality of low level messaging transaction requests or replies, and converting the high level messaging transaction structure into network protocol packets. In still another example, the method further includes converting single-byte based monitor read or write commands into multi-byte monitor read or write requests. In another example, the method further includes re-translating network protocol formatted monitor control commands from a network protocol format to produce monitor control commands intended for communication over a multi-wire bidirectional bus, and controlling operation of a monitor based on the produced monitor control commands intended for communication over the multi-wire bidirectional bus. In another example, the network protocol format includes an internet protocol (IP) format, and the network protocol port includes an internet protocol (IP) port.

[0017] In another exemplary embodiment of the present disclosure, a method carried out by an electronic device is provided. The method includes translating network protocol formatted monitor control commands from a network protocol format to produce monitor control commands intended for communication over a multi-wire bidirectional bus. The method further includes controlling operation of a monitor based on the produced monitor control commands intended for communication over the multi-wire bidirectional bus. In one example, the network protocol format includes an internet protocol (IP) format.

[0018] In another exemplary embodiment of the present disclosure, a wireless device is provided including a wireless transceiver and logic operatively coupled to the wireless transceiver. The logic is operative to translate monitor control commands to an internet protocol (IP) format to produce IP formatted monitor control commands and to communicate the IP formatted monitor control commands to an IP port dedicated for communicating IP formatted monitor control commands. In one example, the logic is operative to identify an IP port of a destination device, such as a display sink, as the dedicated IP port.

[0019] In yet another exemplary embodiment of the present disclosure, a wireless device is provided including a wireless transceiver and logic operatively coupled to the wireless transceiver. The logic is operative to translate internet protocol (IP) formatted monitor control commands from an IP format to produce monitor control commands intended for communication over a multi-wire bidirectional bus and to control operation of a monitor based on the produced monitor control commands intended for communication over the multi-wire bidirectional bus.

[0020] In still another exemplary embodiment of the present disclosure, a wireless display is provided including a monitor and a controller operatively coupled to the monitor and operative to provide image data to the monitor for display on the monitor. The wireless display further includes a wireless device, operatively coupled to the controller, including a wireless transceiver and logic. The logic is operative to translate internet protocol (IP) formatted monitor control commands from an IP format to produce monitor control commands intended for communication over a multi-wire bidirectional bus. The controller controls operation of the monitor based on the produced monitor control commands intended for communication over the multi-wire bidirectional bus.

[0021] In another exemplary embodiment of the present disclosure, a display system is provided including a display source and a wireless display. The display source includes a short range wireless transceiver and logic operatively coupled to the short range wireless transceiver. The logic is operative to translate monitor control commands to an internet protocol (IP) format to produce IP formatted monitor control commands and to communicate the IP formatted monitor control commands to an IP port dedicated for communicating IP formatted monitor control commands. The wireless display includes a monitor, a controller operatively coupled to the monitor for controlling the monitor, and a wireless device operatively coupled to the controller. The wireless device includes a short range wireless transceiver and logic. The short range wireless transceiver of the wireless device is operative to receive the IP formatted monitor control commands from the short range wireless transceiver of the display source. The logic of the wireless device is operative to translate the received IP formatted monitor control commands from the IP format to produce monitor control commands intended for communication over a multi-wire bidirectional bus. The controller controls operation of the monitor based on the produced monitor control commands intended for communication over the multi-wire bidirectional bus. In one example, the IP port dedicated for communicating IP formatted monitor control commands is an IP port associated with the wireless device of the wireless display.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] The invention will be more readily understood in view of the following description when accompanied by the below figures and wherein like reference numerals represent like elements:

[0023] FIG. **1** is a block diagram of a prior known image display system including a display source and a display sink communicating over a wired communication link;

[0024] FIG. **2** is a block diagram of an exemplary image display system in accordance with an embodiment including a display source with an integrated wireless source device and a display sink with an integrated wireless sink device;

[0025] FIG. **3** is a block diagram of another exemplary image display system in accordance with an embodiment including a display source with a discrete wireless source device and a display sink with a discrete wireless sink device;

[0026] FIG. **4** is a flow chart of an exemplary method of operation of the display source of FIGS. **2** and **3** for communicating monitor control commands over an internet protocol (IP) communication interface;

[0027] FIG. **5** is a flow chart of an exemplary method of operation of the display source of FIGS. **2** and **3** for translating monitor control commands to an IP format to produce IP formatted monitor control commands;

[0028] FIG. **6** is a flow chart of an exemplary method of operation of the display sink of FIGS. **2** and **3** for providing monitor control commands to a monitor controller;

[0029] FIG. **7.1** illustrates exemplary read and write request messaging transaction structures provided with the wireless source device of FIGS. **2** and **3**;

[0030] FIG. **7.2** illustrates exemplary read and write reply messaging transaction structures provided with the wireless sink device of FIGS. **2** and **3**;

[0031] FIG. **8** is a block diagram of another exemplary image display system including an integrated wireless display source and a discrete wireless display sink;

[0032] FIG. **9** is a block diagram of another exemplary image display system including a discrete wireless display source and a discrete wireless display sink;

[0033] FIG. **10** is a block diagram of another exemplary image display system including a discrete wireless display source and a discrete wireless display sink;

[0034] FIG. **11** is a block diagram of an exemplary discrete wireless display sink of FIGS. **8-10**; and

[0035] FIG. **12** is a block diagram of exemplary configurations of the image display systems of FIGS. **2** and **3**.

DETAILED DESCRIPTION

[0036] The term "logic" or "control logic" as used herein may include software and/or firmware executing on one or more programmable processors, application-specific integrated circuits (ASICs), field-programmable gate arrays (FPGAs), digital signal processors (DSPs), hardwired logic, or combinations thereof. Therefore, in accordance with the embodiments, various logic may be implemented in any appropriate fashion and would remain in accordance with the embodiments herein disclosed.

[0037] The term "remote communication" and "remote device" and variations thereof, as used herein, refers to communication and to devices adapted for communication over an internet protocol (IP) wireless or wired communication link, such as a Transmission Control Protocol/Internet Protocol (TCP/IP) or a User Datagram Protocol (UDP), for example.

[0038] FIG. **2** illustrates an exemplary image display system **100** according to various embodiments that is configured to communicate monitor control commands and other monitor data over an internet protocol (IP) communication interface **140**. Image display system **100** may be viewed as modifying the known image display system **10** described in FIG. **1**. For example, display source **112** of FIG. **2** may be viewed as a modification of the display source **12** of FIG. **1** further including a wireless source device **142**, and display sink **114** of FIG. **2** may be viewed as a modification of the display sink **14** of FIG. **1** further including a wireless sink device **144**. Like components of image display system **10** of FIG. **1** and image display system **100** of FIG. **2** are provided with like reference numbers. Various other arrangements of internal and external components and corresponding connectivity of image display system **100**, that are alternatives to what is illustrated in the figures, may be utilized and such arrangements of internal and external components and corresponding connectivity would remain in accordance with the embodiments herein disclosed.

[0039] Display source **112** includes memory **20**, image provider **18**, and display interface **22**, as described herein with respect to FIG. **1**. Wireless source device **142** of display source **112** is operatively coupled to display interface **22** via audio/video bus **32***a* for communicating audio, video, other image data, and various controls from image provider **18** to wireless source device **142**. Audio/video (A/V) bus **32***a* illustratively provides unidirectional communication from image provider **18** to wireless source device **142**, although A/V bus **32***a* may alternatively be bi-directional. An I2C bus **146** communicates monitor control commands and monitor capability information, described above with respect to I2C bus **34** of FIG. **1**, between image provider **18** and wireless source device **142**.

[0040] Display sink **114** includes memory **28**, monitor controller **26**, monitor **16**, and display interface **24**, as described herein with respect to FIG. **1**. Wireless sink device **144** of display sink **114** is operatively coupled to display interface **24** via audio/video bus **32***b* for communicating audio, video, other image data, and various controls from wireless sink device **144** to monitor controller **26**. Audio/video (A/V) bus **32***b* illustratively provides unidirectional communication from wireless sink device **144** to monitor controller **26**, although A/V bus **32***b* may alternatively be bi-directional. An I2C bus **156** communicates monitor control commands and monitor capability information, described above with respect to I2C bus **34** of FIG. **1**, between wireless sink device **144** and monitor controller **26**.

[0041] The operation and structure, as well as the data and controls communicated, of I2C bus **146**, **156** is as described above with respect to I2C bus **34** of FIG. **1**. For example, I2C bus **146** communicates EDID information, MCCS commands, and other display data and monitor control commands between image provider **18** and source device **142**, and I2C bus **156** communicates the EDID information, MCCS commands, and other display data and monitor control commands between wireless sink device **144** and monitor controller **26**. In one embodiment, I2C buses **146**, **156** communicate commands and data using DDC and/or CI protocol, described herein. In one embodiment, A/V bus **32***a* and I2C bus **146** are provided in a common, multi-conductor communication bus, and A/V bus **32***b* and I2C bus **156** are provided in a common, multi-conductor communication bus. A/V bus **32***a*, **32***b* and I2C bus **146**, **156** are configured with the same communication interface as respective display interfaces **22**, **24**, which may include a video graphics array (VGA), digital video interface (DVI), high definition multimedia interface (HDMI), DisplayPort (DP), or other communication interface.

[0042] Wireless source device **142** includes a wireless transceiver **150** operative to communicate data and controls wirelessly in an internet protocol (IP) format over a communication link or channel **140** with a wireless transceiver **160** of wireless sink device **144**. For example, transceivers **150**, **160** include wireless antennas that communicate the EDID information, MCCS commands, and other display data and monitor control commands, as well as the audio/video data and other image data and controls received via A/V bus **32***a*, over IP formatted communication link **140**. Exemplary IP formatted protocols of communication link **30** and transceivers **150**, **160** include Transmission Control Protocol/Internet Protocol (TCP/IP) or User Datagram Protocol (UDP), for example. In the illustrated embodiment, wireless transceivers **150**, **160** are short range wireless transceivers operative to communicate at short range distances. Exemplary short range wireless protocols include IEEE 802.11 protocols (e.g., 802.11a, 802.11b, 802.11g, 802.11n, 802.11 ac, 802.11 ad, etc.), Wireless Gigabyte Alliance (WiGig) protocol, Bluetooth, communications access for land mobiles (CALM), and other suitable

short range protocols. For example, in one embodiment using an IEEE 802.11 protocol, transceivers **150**, **160** may communicate at distances of up to several hundred feet or up to several thousand meters. Other protocols may communicate at distances of up to about 30 meters or other suitable distances. Alternatively, transceivers **150**, **160** may configured to communicate at greater distances. In one embodiment, source and sink devices **142**, **144** are operationally compliant with a wireless standard, such as the wireless display standard WFD from WiFi Alliance.

[0043] While wireless source device **142** and wireless sink device **144** illustratively communicate wirelessly over the IP communication link **140**, wireless source device **142** and wireless sink device **144** are also adapted to communicate via a wired IP communication interface, such as over Ethernet cables or other suitable IP communication cables or wires. For example, in one embodiment, transceivers **150**, **160** of source device **142** and sink device **144**, respectively, each include a wired IP communication connector that is adapted to receive an IP communication cable (e.g., Ethernet cable) to connect source device **142** and sink device **144** for IP formatted communication therebetween.

[0044] Referring still to FIG. **2**, source device **142** further includes logic **148** coupled to transceiver **150**. In one embodiment, logic **148** includes one or more processors (e.g. microprocessor, etc.) or other controllers with access to a memory that includes software and/or firmware code containing instructions that, when executed by the processor, cause the processor to perform the functions and operations of source device **142**. Logic **148** may alternatively include discrete logic stored in a memory of source device **142** that is operative to perform the functions and operations of source device **142**. For example, logic **148** is operative to convert the audio, video, and other image data received over audio/video bus **32***a* from image provider **18** into an internet protocol (IP) format suitable for transmission over IP communication link **140**.

[0045] In the illustrated embodiment, logic **148** includes a translator module **154** that is operative to translate or convert monitor control commands and other data received over I2C bus **146** (i.e., from image provider **18**) from the I2C format to an internet protocol (IP) format to produce IP formatted monitor control commands suitable for communication over IP communication link **140** to sink device **144**. The translated monitor control commands include the MCCS commands, described herein, requests for EDID information, or other suitable monitor control commands. For example, translator module **154** is operative to translate read/write requests from image provider **18** sent over I2C bus **146**, such as a request for the EDID information stored at memory **28** of display sink **114**, to IP formatted requests. In one embodiment, logic **148** sends the IP formatted monitor control commands to transceiver **150** by writing to a memory accessible by transceiver **150** and/or to I/O locations associated with transceiver **150**.

[0046] Logic **148** identifies an IP port (e.g., IP number or address) associated with translator module **164** of sink device **144**, and designates the identified IP port for the communication of the IP formatted monitor control commands and other data over communication link **140** with translator module **164**. In one embodiment, logic **148** of source device **142** negotiates with logic **158** of sink device **144** to determine the dedicated IP ports of translator module **164** and translator module **154**. In one embodiment, translator modules **154** and **164** communicate over network layer **3**. Logic **148** also identifies a media access control (MAC) address of transceiver **160** of sink device **144** to identify the destination device (transceiver **160**) that receives the communicated information and data. In one embodiment, transceivers **150**, **160** include both data link layer **2** and physical layer **1**. In one embodiment, a MAC frame communicated between transceivers **150**, **160** carries the layer **3** data as the MAC frame payload.

[0047] Similarly, translator module **154** is operative to retranslate IP formatted commands and data, such as monitor capability data (e.g., EDID information), received over communication link **140** from sink device **144** into a format suitable for communication over I2C bus **146**. For example, upon receiving IP formatted monitor capability data from display sink **114** via transceiver **150** at a designated IP port, translator module **154** converts the IP formatted monitor capability data into a format intended for communication over I2C bus **146**, such as DDC and/or CI protocol.

[0048] Referring still to FIG. **2**, sink device **144** further includes logic **158** coupled to transceiver **160**. In one embodiment, logic **158** includes one or more processors (e.g. microprocessor, etc.) or other controller with access to a memory that includes software and/or firmware code containing instructions that, when executed by the processor, cause the processor to perform the functions and operations of sink device **144**. Logic **158** may alternatively include discrete logic stored in a memory of sink device **144** that is operative to perform the functions and operation of sink device **144**. For example, logic **158** is operative to convert the IP formatted audio, video, and other image data received over IP communication link **140** from display source **112** into a format suitable for transmission over I2C bus **156** of display sink **114**, such as DDC/CI protocol format.

[0049] In the illustrated embodiment, logic **158** includes a translator module **164** that is operative to translate or convert IP formatted monitor control commands and other data received over IP communication link **140** into monitor control commands and data intended for communication over I2C bus **156** of display sink **114**. The translated monitor control commands include the MCCS commands, requests for EDID information, or other suitable monitor control commands received from display source **112**. For example, translator module **164** is operative to translate IP formatted read/write requests from display source **112** sent over IP communication link **140**, such as a request for the EDID information stored at memory **28** of display sink **114**, to read/write requests suitable for communication over I2C bus **156**. Upon translation, logic **158** communicates the translated monitor control commands over I2C bus **156** and interface **24** to monitor controller **26**, and monitor controller **26** controls monitor **16** based on the translated monitor control commands. To communicate with display source **112**, logic **158** identifies an IP port (e.g., IP number or address) associated with translator module **154** of source device **142**, and designates the identified IP port for the communication of the IP formatted monitor control commands, monitor capability data, and other data over communication link **140** with translator module **154**. In one embodiment, logic **158** and logic **148** negotiate the designation of the IP ports of translator modules **154**, **164**, as described herein. Logic **158** also identifies a media access control (MAC) address of transceiver **150** of source device **142** to identify the device (transceiver **150**) that provides or receives communicated information and data.

[0050] Translator module **164** is further operative to re-translate or convert monitor capability data and other data received over I2C bus **156** (i.e., from monitor controller **26**) from the I2C format to an internet protocol (IP) format to produce IP formatted monitor capability data suitable for communication over IP communication link **140** to source device **142**. For example, upon translator module **154** receiving and translating a request from display source **112** for monitor capability data (e.g., EDID structure) and sending the I2C formatted request to monitor controller **26**, monitor controller **26** provides the monitor capability data in an I2C format to sink device **144** via I2C bus **156**. Translator module **164** then translates the monitor capability data from the I2C intended format to IP formatted monitor capability data and provides the data to transceiver **160** for communication over IP communication link **140** to transceiver **150**. In one embodiment, logic **158** sends the IP formatted data to transceiver **160** for communication over link **140** by writing to a memory accessible by transceiver **160** and/or to I/O locations associated with transceiver **160**.

[0051] Logic **148** of source device **142** and logic **158** of sink device **144** are configured to translate multimedia and control data communicated over audio/video buses **32***a*, **32***b* between the IP format and the native format (e.g., HDMI, DVI, VGA, DP, etc.) such that the data may be communicated over IP communication link **140** and to the respective image provider **18** and monitor controller **26**. While audio/video buses **32***a*, **32***b* and IP communication link **140** of image display system **100** illustratively communicate audio and video data, other image data, such as graphics data, etc., may also be communicated via buses **32***a*, **32***b* and link **140**.

[0052] In one embodiment, image provider **18** is configured to control the power settings and on/off status of monitor **16** using monitor control commands sent over communication link **140**.

[0053] For example, image provider **18** may issue MCCS commands to turn on and off monitor **16**, to reduce or manage the power of monitor **16**, and/or to control other power settings of monitor **16**.

[0054] Source device **142** and sink device **144** of FIG. **2** are illustratively integrated with display source **112** and display sink **114**, respectively. For example, source device **142** and sink device **144** are provided as one or more chips on a common circuit board or within a common housing of components of respective display source **112** and display sink **114**.

[0055] In another embodiment, logic **148** of integrated source device **142** is included in image provider **18** of display source **112**. For example, referring to FIG. **12**, another exemplary display source **870** is illustrated including image provider **18** providing IP formatted I2C messaging transactions (e.g., monitor capability data requests, monitor control commands, etc.) to wireless transceiver (Wi-Fi device) **150** as internet protocol (IP) packets. Integrated display source **870** may be viewed as modifying the display source **112** described in FIG. **2**. In the display source **870** of FIG. **12**, logic **148** of image provider **18** is operative to translate read/write requests (e.g., from an operating system of image provider **18**) intended for communication over an I2C bus into IP packets containing IP formatted monitor control commands and other data, and image provider **18** communicates the IP packets over bus **871** to transceiver **150** for communication over the IP link **140** (see FIG. **2**). Similarly, logic **148** is operative to re-translate IP formatted commands and data, such as monitor capability data (e.g., EDID information), received over communication link **140** from display sink **114** (FIG. **2**) into a format readable by image provider **18**, such as a format intended for communication over an I2C bus. An exemplary bus **871** includes a peripheral component interconnect express (PCIe) bus, a USB bus, or another suitable bus operative to communicate IP formatted information and data. IP formatted audio and video data is also transmitted over bus **871** of FIG. **12** for communication with transceiver **150**. In this embodiment, a physical I2C bus **146** (see FIG. **2**) is not utilized for the communication of the monitor control commands and capability data. In one embodiment, logic **148** is provided in one or more CPU cores and/or GPU cores, or in other suitable processors, of image provider **18**.

[0056] Logic **148** also identifies an IP port (e.g., IP number or address) associated with translator module **164** of sink device **144**, and designates the identified IP port (e.g., communicates the IP port to an operating system of image provider **18**) for the communication of the IP formatted monitor control commands and other data over communication link **140** with translator module **164**, as described herein. Logic **148** also identifies a MAC address of transceiver **160** of sink device **144** to identify the device (transceiver **160**) that receives or provides the communicated information and data, as described herein.

[0057] Referring again to FIG. **2**, either or both source device **142** and sink device **144** may alternatively be discrete devices coupled externally to respective display source **112** and display sink **114**. For example, referring to FIG. **3**, an image display system **200** includes a discrete wireless source device **242** coupled externally to display source **212** with a connector **270** and a discrete wireless sink device **244** coupled externally to display sink **214** with a connector **272**. Image display system **200** of FIG. **3** may be viewed as modifying the image display system **100** of FIG. **2**, i.e., discrete wireless source device **242** of FIG. **3** replaces integrated wireless source device **142** of FIG. **2**, and discrete wireless sink device **244** of FIG. **3** replaces integrated wireless sink device **144** of FIG. **2**.

[0058] In one embodiment, source device **242** and sink device **244** are small, portable devices, such as dongles, including respective connectors **270**, **272** configured to plug into an external port or connector of respective display source **212** and display sink **214**. In one embodiment, each device **242**, **244** is less than about two inches in length and one inch in width. Other suitable sizes of devices **242**, **244** may be provided. Connectors **270**, **272** illustratively include the respective A/V buses **32***a*, **32***b* for communicating audio, video, and other image data and I2C buses **146**, **156** for communicating monitor control commands, monitor capability data, and other data, as described herein with respect to FIGS. **1** and **2**. Connectors **270**, **272** may include an HDMI, DP, universal serial bus (USB) interface, or other suitable interface configured to mate with a corresponding port of the respective display interface **22**, **24**. In one embodiment, depending on the interface type of connectors **270**, **272**, respective logic **248**, **258** may include a module for converting the communicated data and controls into a format suitable for communication over the connector **270**, **272**. For example, a USB type connector **270**, **272** may require an additional translation of the communicated data between the USB supported format and the IC2 or IP supported format.

[0059] Source and sink devices **242**, **244** include the components and functionality of respective source and sink

devices **142**, **144** of FIG. **2**. For example, source device **242** includes a wireless transceiver **250** for communication of monitor control commands, monitor capability data, and other data converted from an I2C format to an IP format, as described herein with respect to transceiver **150** of FIG. **2**. Source device **242** further includes logic **248** including a translator module **254** corresponding to logic **148** and translator module **154** of FIG. **2**, described herein. Similarly, sink device **244** includes a wireless transceiver **260** for communication of monitor control commands, monitor capability data, and other data converted from an I2C format to an IP format, as described herein with respect to transceiver **160** of FIG. **2**. Sink device **244** further includes logic **258** including a translator module **264** corresponding to logic **158** and translator module **164** of FIG. **2**, described herein.

[0060] Source and sink devices **242**, **244** are also adapted to communicate via a wired IP communication interface **140**, such as over Ethernet cables or other suitable IP communication cables or wires. Similar to transceivers **150**, **160** of FIG. **2**, transceivers **250**, **260** may each include a wired IP communication port or connector that is adapted to receive an IP communication cable (e.g., Ethernet cable) to connect source device **242** and sink device **244** for IP formatted communication therebetween.

[0061] FIG. **4** illustrates a flow diagram **400** of an exemplary operation performed by display source **112** of FIG. **2** (or source device **242** of FIG. **3** or display source **870**, **872**, **874** of FIG. **12**). While FIG. **4** is described with respect to an internet protocol (IP), the operation of FIG. **4** may be used with any network protocol. At block **402**, monitor control commands are translated to an internet protocol (IP) format to produce IP formatted monitor control commands. For example, monitor control commands received from image provider **18** in a format intended for multi-wire, bi-directional communication bus (e.g., I2C bus **146**) are translated with translator module **154** to an IP format to produce IP formatted monitor control commands. The monitor control commands may include MCCS commands, data requests (e.g., EDID information requests), or other suitable commands for controlling monitor **16**.

[0062] At block **404**, the IP formatted monitor control commands are communicated to an IP port dedicated for communicating IP formatted monitor control commands. The IP formatted monitor control commands communicated to the dedicated IP port, such as an IP port of a destination device (e.g., sink device **144**), are transmitted over IP communication link **140** for receipt at sink device **144**. In one embodiment, communicating the IP formatted monitor control commands at block **404** includes identifying an IP port associated with a destination device, such as translator module **164** of sink device **144**, and dedicating the IP port for communication of the IP formatted monitor control commands. For example, the logic **148** identifies an IP port, such as a port address or other suitable identifier, associated with translator module **164** of sink device **144** and dedicates that IP port for communication of the monitor control commands and monitor capability data. In one embodiment, a first IP port is identified as a dedicated port for communicating monitor control commands, and a second IP port is identified as a dedicated port for communicating monitor capability data. Logic **148** also identifies an IP port associated with source device **142** (e.g., associated with translator module **154**) for communication between translator modules **154**, **164**. In one embodiment, source device **142** and sink device **144** negotiate to dedicate the IP ports associated with translator modules **154**, **164**. The identified IP port(s) is static and, once established, is used for communicating multiple IP formatted monitor control commands and data, although the dedicated IP port may alternatively be dynamically determined. As described herein, the communication of the IP formatted monitor control commands at block **404** may be via a wireless or wired IP interface **140**.

[0063] Upon receipt of the IP formatted monitor control commands, translator module **164** of sink device **144** is operative to re-translate the IP formatted monitor control commands from the IP format to produce monitor control commands intended for communication over a multi-wire bidirectional bus, such as I2C bus **156**, as described herein. Operation of monitor **16** is controlled based on the produced monitor control commands intended for communication over the multi-wire bidirectional bus, as described herein.

[0064] FIG. **5** illustrates a flow diagram **500** of an exemplary translation operation of block **402** of FIG. **4**. Referring to FIG. **5**, a high level messaging transaction structure is generated by translator module **154**, for example, from a plurality of low level messaging transaction requests or replies, as illustrated at block **502**. In particular, the monitor control commands provided over I2C bus **146** to translator module **154** include a plurality of low level messaging transaction requests. For example, in one embodiment, the monitor control commands are comprised of a plurality of single byte read requests or a single byte write requests intended for serial communication over I2C bus **146**. The read requests may include requests to read monitor capability data (e.g., EDID structure) of monitor **16**, and the write requests may include control commands (e.g., MCCS commands) operative to control operation of monitor **16**, as described herein. Translator module **154** generates a high level (multi-byte) messaging transaction structure consisting of one or more low level (single byte) messaging transaction requests (e.g., read or write requests), i.e., one or more monitor control commands. In other words, the high level messaging transaction structure consists of a grouping of multiple low level requests and may comprise a multiple bytes of data. In one embodiment, each high level messaging transaction structure consists of up to 128 bytes, although other data structure sizes may be provided. See, for example, read and write request messaging transaction structures **700** and **720** illustrated in FIG. **7.1** and described herein.

[0065] At block **504**, the high level messaging transaction structure is converted into internet protocol (IP) packets for communication over IP link **140**. In particular, upon generating the high level messaging transaction structure at block **502** consisting of the monitor control commands, one or more IP packets suitable for communication over IP communication link **140** are created from the high level messaging transaction structure and communicated to sink device **144**.

[0066] In another exemplary translation operation of block **402** of FIG. **4**, after an operating system of image provider **18** issues an application programming interface (API) that includes a monitor control command and/or a request for monitor capability data (e.g., EDID request), a graphics driver of image provider **18** translates the API into one or more low level messaging transaction structures (e.g., single byte I/O read/writes). The low level messaging transaction structures received at source device **142** (e.g., over I2C bus **146**) are accumulated by logic **148** and converted by logic **148** into one or more IP formatted, high level messaging transac-

tion structures, as described herein. Logic **148** then translates the high level messaging transaction structures into IP packet payloads of one or more IP packets. The header of the IP packet also includes a source IP port (e.g., IP address of translator module **154**) and a destination IP port (e.g., IP address of translator module **164**). Transceiver **150** then transmits the IP packets over link **140** to the dedicated IP port associated with translator module **164** of display sink **114**.

[0067] In the embodiment of integrated display source **870** described in FIG. **12**, the translation of the monitor control commands into IP packets is done within logic **148** of image provider **18**. For example, after an operating system of image provider **18** issues an API that includes a monitor control command and/or a request for monitor capability data (e.g., EDID request), a graphics driver of image provider **18** translates the API into one or more IP formatted, high level messaging transaction structures and then notifies a driver of the wireless transceiver **150**, i.e., a driver contained in logic **148**. Logic **148** then identifies an IP port of translator module **164** of sink device **144** and calls the operating system driver to send the IP formatted, high level messaging transaction structures as IP packets to the designated IP port of sink device **144**. The IP packets containing the high level messaging transaction structures are transferred from image provider **18** to transceiver **150** over bus **871** (e.g., PCIe bus or USB), and transceiver **150** communicates the IP packets to the dedicated IP port of sink device **144** (FIG. **2**). As such, an I2C bus is not used to communicate the monitor control commands and data in this embodiment.

[0068] FIG. **6** illustrates a flow diagram **600** of an exemplary operation performed by sink device **144** (and/or display sink **114**) of FIG. **2** (or sink device **244** and/or display sink **214** of FIG. **3**). While FIG. **6** is described with respect to an internet protocol (IP), the operation of FIG. **4** may be used with any network protocol. At block **602**, IP formatted monitor control commands are translated from an IP format to produce monitor control commands intended for communication over a multi-wire bidirectional bus, such as I2C bus **156**. In particular, upon receipt of the IP formatted monitor control commands from source device **142**, translator module **164** of sink device **144** is operative to translate the IP formatted monitor control commands to produce monitor control commands intended for communication over a multi-wire bidirectional bus, such as I2C bus **156**. In one embodiment, translator module **164** reverses the translation performed by translation module **154**. For example, translator module **164** converts the IP packets received from display source **112** into one or more high level messaging transaction structures (e.g., multi-byte structure containing one or more read/write requests) and generates a plurality of low level messaging transaction requests (e.g., single-byte read or write commands) that are suitable for communication over a multi-wire bidirectional bus, such as I2C bus **156**.

[0069] At block **604**, the operation of a monitor, such as monitor **16**, is controlled based on the produced monitor control commands intended for communication over the multi-wire bidirectional bus (e.g., I2C bus **156**). In one embodiment, sink device **144** controls monitor **16** by communicating the produced monitor control commands over I2C bus **156** to monitor controller **26**, and monitor controller **26** controls the operation of monitor **16** based on the produced monitor control commands, as described herein.

[0070] In one embodiment, when the produced monitor control command includes a read request operative to read monitor capability data (e.g., EDID structure, etc.) from monitor **16**, monitor controller **26** is operative to communicate I2C formatted monitor capability data (e.g. EDID information) back to translator module **164** for communication back to image provider **18** of display source **112**. In this embodiment, translator module **164** translates the requested monitor capability data (e.g., EDID information, etc.) intended for communication over a multi-wire bidirectional bus (e.g., I2C bus **156**) to an IP format to produce IP formatted monitor capability data. Sink device **144** then communicates the produced IP formatted monitor capability data to an IP port (e.g., an IP port of translator module **154** of source device **142**) dedicated for communicating IP formatted monitor capability data, as described herein. In one embodiment, logic **158** of sink device **144** identifies an IP port associated with a destination device, i.e., translator module **154** of source device **142**, and dedicates the identified IP port for communicating the IP formatted monitor capability data.

[0071] Referring to FIGS. **7.1** and **7.2**, several tables are illustrated that define exemplary high level messaging transaction structures that are generated from one or more low level messaging transaction requests and replies (e.g., single-byte, I2C formatted monitor control commands or replies), as described herein. Upon conversion to IP packets, the high level messaging transaction structures containing the monitor control commands and/or data replies may be communicated between the source device **142** and sink device **144** of FIG. **2** over IP communication link **140**. Exemplary high level messaging transaction structures described in FIGS. **7.1** and **7.2** include read and write request data structures from display source **112** (see FIG. **7.1**) and read and write reply (acknowledge) data structures from display sink **114** (see FIG. **7.2**). Other suitable data structures may be provided.

[0072] Referring to FIG. **7.1**, the data structure of table **700**, which may be stored in a memory accessible by logic **148** of FIG. **2**, converts I2C formatted, low level requests for monitor capability data (received from image provider **18** over I2C bus **146**) into a high level messaging transaction structure ("remote I2C read request structure") for communication over IP interface **140**. In the illustrated embodiment, a low level request for monitor capability data includes both I2C read requests and I2C write transactions or requests. For example, to request monitor capability data, image provider **18** first issues one or more I2C bus write requests which sets up the I2C read address offset associated with display sink **114** (FIG. **2**), to identify a location of the monitor capability data (e.g., the EDID structure). Following the write request (s), image provider **18** issues a series of I2C formatted read requests that identify the monitor capability data to be read from display sink **114**. In one embodiment, the I2C formatted read requests are single-byte requests, although the requests may alternatively be multi-byte requests. The data structure of table **700** is operative to collect these I2C bus write and read requests from image provider **18** (i.e., using the "for" loop **702**) into a group or a block of low level requests to generate a high level messaging transaction read data structure that comprises multiple bytes of data. In one embodiment, each high level messaging transaction structure generated for monitor capability requests includes up to 128 bytes of data and includes at least one write request to identify the I2C read address and/or to set up the read request offset. In the illustrated embodiment, source device **142** sends the gener-

ated remote read request structure to sink device **144** using a TCP/IP port number assigned to initiate an I2C read from display sink **114**.

[0073] The data structure of table **720** of FIG. **7.1**, which may be stored in a memory accessible by logic **148** of FIG. **2**, converts I2C formatted, low level monitor control commands (received from image provider **18** over I2C bus **146**) into a high level messaging transaction structure ("remote I2C write request structure") for communication over IP interface **140**. The converted monitor control commands may include MCCS commands, as described herein, in the form of one or more single byte I2C write requests. The data structure of table **720** is operative to collect these I2C bus write requests from image provider **18** (i.e., using the "for" loop **722**) into a group or a block of low level requests to generate a high level messaging transaction write structure that comprises multiple bytes of data. In one embodiment, each high level messaging transaction structure generated for monitor control commands includes around 6 to 32 bytes of requests, although other suitable sizes may be provided. In the illustrated embodiment, source device **142** sends the generated remote write request structure to sink device **144** using a TCP/IP port number assigned to initiate I2C writes to display sink **114**.

[0074] The data structures of tables **730**, **740**, **750**, and **760** of FIG. **7.2**, which may be stored in a memory accessible by logic **158** of sink device **144** of FIG. **2**, converts I2C formatted, low level read and write reply acknowledgements (received from monitor controller **26** over I2C bus **156**) into high level messaging transaction structures for communication over IP interface **140**. The high level messaging transactions structures may include a single byte (e.g., a single acknowledgement reply from monitor controller **26**) or multiple bytes of data. The data structures of Tables **730-760** are illustratively acknowledgement replies that indicate the success or failure of the receipt and/or implementation of a monitor control command or of a monitor capability request. For example, tables **730** and **750** define a data structure for converting one or more low level replies acknowledging a read or write success into a high level data structure. Tables **740** and **760** define a data structure for converting one or more low level replies acknowledging a read or write failure into a high level data structure. In the illustrated embodiment, sink device **144** sends the generated remote reply acknowledgment structures to source device **142** using TCP/IP port numbers assigned to indicate the success or failure of corresponding reads and writes performed and/or read data presented.

[0075] FIGS. **8-12** illustrate additional exemplary configurations of the image display systems **100**, **200** of FIGS. **2** and **3**. Each configuration illustrated in FIGS. **8-12** includes the functionality and operational capabilities of the image display systems **100**, **200** of FIGS. **2** and **3**. In one embodiment, the image display systems of FIGS. **8-12** conform to a wireless standard, such as the wireless display standard WFD of the Wi-Fi Alliance.

[0076] Referring initially to FIG. **8**, an image display system **800** includes an integrated wireless display source **802** and a discrete wireless display sink **804**. Display source **802** includes an integrated wireless source device **810**. Display sink **804** includes a discrete wireless sink device **805**, illustratively a sink dongle **805**, that is connected externally to an interface port (e.g., HDMI, DP, etc.) of a display device **806**, such as a monitor, television, projector, etc. Source device **810** converts the low level I2C read/writes received from an image provider (not shown) of display source **802** to high level I2C messaging transactions structures communicated over the air to sink dongle **805**, as described herein. Sink dongle **805** arbitrates the high level messaging transaction structures to low level I2C read/writes and provides the low level I2C read/writes to display device **806**. Display device **806** further includes an EDID structure **808** that is readable by display source **802**, as described herein.

[0077] In the embodiment of FIG. **8**, display device or monitor **806** is controlled with MCCS commands and display source **802** reads unfiltered EDID information using the remote I2C read/write configuration (i.e., the transmission of the IP formatted I2C read/writes). Display source **802** includes an application (e.g. processed by an image provider) that makes display mode decisions based on the unfiltered EDID information as well as H.264 codec capability. In one embodiment, display source **802** is configured to read EDID information from different display devices **806** regardless of differences in the EDID structure **808** among the different display devices **806**. As such, in one embodiment, the remote I2C read/write configuration provides an I2C tunneling method that is compatible with various image display systems configured for I2C bus communication.

[0078] Referring to FIG. **9**, another exemplary image display system including a discrete wireless display source **822** and the discrete wireless display sink **804** of FIG. **8**. Discrete wireless display source **822** includes a wireless source device **824**, illustratively a source dongle **824**, that is connected to an external interface port (e.g., HDMI, DP, etc.) of display source **826**. In this embodiment, a display application of display source **826** obtains access to the wireless display device capability (e.g. H.264 codec subelement, etc.) of display device **806** through proprietary means. In the illustrated embodiment, display source **826** does not have access to the wireless capability of the source dongle **824**. As in FIG. **8**, display device or monitor **806** is controlled with MCCS commands and display source **826** reads unfiltered EDID information using the remote I2C read/write configuration (i.e., the transmission of the IP formatted I2C read/writes). Display source **826** includes an application that makes display mode decisions based on the unfiltered EDID information.

[0079] Referring to FIG. **10**, another exemplary image display system **840** is illustrated. System **840** is identical to system **820** of FIG. **9** with the exception of the EDID information being filtered by source dongle **824** before receipt by display source **826**. In this embodiment, the display sink **804** does not filter the EDID information, and EDID filtering is performed by source dongle **824** only in the case where wireless device capability of dongle **824** cannot be communicated to display source **826**. In one embodiment, display modes within the wireless display (e.g., WFD by Wi-Fi Alliance) capability are not filtered even if it is not on the H.264 codec subelement tables.

[0080] Referring to FIG. **11**, another exemplary configuration of discrete wireless display sink **804** of FIGS. **8-10** is illustrated. Display sink dongle **805** of FIG. **11** includes a wireless or Wi-Fi device **850**, such as a wireless transceiver, that receives high level Remote I2C Read/Write structures over the air from a display source, as described herein. Dongle **805** further includes logic and other Wi-Fi components **852**. Logic **852** includes an I2C master node **854** (e.g., microprocessor, discrete logic, etc.) that issues clock and data/address requests with an I2C slave node **856** of display device **806** to control I2C communication over the I2C bus **860** of HDMI interface **858**.

[0081] In one embodiment, logic **852** arbitrates the Remote I2C Read/Write requests among other internal I2C read/write requests. After arbitration, the display sink **805** initiates a series of I2C bus read/writes (using its I2C master node **854**) as requested by the Remote I2C Read/Write request structure. After the completion of an entire series of I2C bus read/writes, display sink **805** sends a Remote I2C acknowledge reply messaging structure back to the display source.

[0082] Referring to FIG. **12**, various configurations of the image display systems **100**, **200** of FIGS. **2** and **3** are illustrated. Exemplary display source configurations include an integrated wireless display source **870** (described herein), a discrete wireless display source **872** with a network interface, and a discrete wireless display source **874** with a display interface. Display source **872** illustratively includes a USB interface between the display source and the wireless source dongle, while display source **874** includes a DP, HDMI, or other suitable interface between the display source and the wireless source dongle. Exemplary display sink configurations include an integrated wireless display sink **876** and a discrete wireless display sink **878** with a display interface, such as DP, HDMI, or other suitable interface. In the exemplary configurations of FIG. **12**, the remote I2C messaging transaction structure may be tunneled through Wi-Fi as IP packets (e.g., TCP/IP), as described herein. Further, in one embodiment, Wi-Fi logic is not required to parse I2C commands as they may be generated/interpreted by the source/sink logic above Wi-Fi.

[0083] Among other advantages, the method and apparatus allows for communication of monitor control commands, monitor capability information, and other monitor data between a display source and a display sink using an internet protocol (IP) communication interface, such as a wireless interface. The enabled communication of monitor control commands, capability data, and other data intended for communication over an I2C bus, for example, allows a display source communicating over an IP communication interface to control the display operations and the display features and capabilities of the display system, as described herein. Other advantages will be recognized by those of ordinary skill in the art.

[0084] While this invention has been described as having preferred designs, the present invention can be further modified within the spirit and scope of this disclosure. This application is therefore intended to cover any variations, uses, or adaptations of the invention using its general principles. Further, this application is intended to cover such departures from the present disclosure as come within known or customary practice in the art to which this disclosure pertains and which fall within the limits of the appended claims.

What is claimed is:

1. A method carried out by an electronic device comprising:

translating monitor control commands to a network protocol format to produce network protocol formatted monitor control commands; and

communicating the network protocol formatted monitor control commands to a network protocol port dedicated for communicating network protocol formatted monitor control commands.

2. The method of claim **1**, wherein translating the monitor control commands to a network protocol format to produce network protocol formatted monitor control commands comprises translating monitor control commands intended for communication over a multi-wire bidirectional bus, and wherein the method comprises wirelessly communicating the network protocol formatted monitor control commands.

3. The method of claim **1**, wherein communicating the network protocol formatted monitor control commands to the dedicated network protocol port comprises identifying a network protocol port of a destination device and dedicating the identified network protocol port for communicating network protocol formatted monitor control commands.

4. The method of claim **1**, wherein translating the monitor control commands to a network protocol format to produce network protocol formatted monitor control commands comprises:

generating a high level messaging transaction structure from a plurality of low level messaging transaction requests or replies; and

converting the high level messaging transaction structure into network protocol packets.

5. The method of claim **4**, further comprising converting single-byte based monitor read or write commands into multi-byte monitor read or write requests.

6. The method of claim **1**, further comprising:

re-translating network protocol formatted monitor control commands from a network protocol format to produce monitor control commands intended for communication over a multi-wire bidirectional bus; and

controlling operation of a monitor based on the produced monitor control commands intended for communication over the multi-wire bidirectional bus.

7. The method of claim **6**, further comprising communicating the produced monitor control commands over the multi-wire bidirectional bus in the monitor to control the monitor operation.

8. The method of claim **1**, wherein the network protocol format includes an internet protocol (IP) format, and wherein the network protocol port includes an internet protocol (IP) port.

9. A method carried out by an electronic device comprising:

translating network protocol formatted monitor control commands from a network protocol format to produce monitor control commands intended for communication over a multi-wire bidirectional bus; and

controlling operation of a monitor based on the produced monitor control commands intended for communication over the multi-wire bidirectional bus.

10. The method of claim **9**, wherein translating the network protocol formatted monitor control commands to produce monitor control commands intended for communication over a multi-wire bidirectional bus comprises generating a plurality of low level messaging transaction requests or replies from a high level messaging transaction structure.

11. The method of claim **10**, further comprising converting multi-byte monitor read or write requests into single-byte based monitor read or write commands.

12. The method of claim **9**, further comprising:

translating monitor capability data intended for communication over a multi-wire bidirectional bus to a network protocol format to produce network protocol formatted monitor capability data; and

communicating the produced network protocol formatted monitor capability data to a network protocol port dedicated for communicating network protocol formatted monitor capability data.

13. The method of claim **12**, wherein communicating the produced network protocol formatted monitor capability data to the dedicated network protocol port comprises identifying a network protocol port of a destination device and dedicating the identified network protocol port for communicating the produced network protocol formatted monitor control commands.

14. The method of claim **9**, further comprising receiving the network protocol formatted monitor control commands wirelessly from a remote display source.

15. The method of claim **9**, further comprising communicating the produced monitor control commands over the multi-wire bidirectional bus in the monitor to control the monitor operation.

16. The method of claim **9**, wherein the network protocol formatted monitor control commands include internet protocol (IP) formatted monitor control commands, and wherein the method comprises translating IP formatted monitor control commands from an IP format to produce monitor control commands intended for communication over a multi-wire bidirectional bus.

17. A wireless device comprising:

a wireless transceiver;

logic, operatively coupled to the wireless transceiver, operative to translate monitor control commands to an internet protocol (IP) format to produce IP formatted monitor control commands and to communicate the IP formatted monitor control commands to an IP port dedicated for communicating IP formatted monitor control commands.

18. The wireless device of claim **17**, wherein the monitor control commands are intended for communication over a multi-wire bidirectional bus.

19. The wireless device of claim **18**, wherein the multi-wire bidirectional bus comprises an inter-integrated circuit bus.

20. The wireless device of claim **17**, wherein the logic is further operative to identify an IP port of a destination device as the dedicated IP port.

21. The wireless device of claim **17**, wherein the logic is further operative to generate a high level messaging transaction structure from a plurality of low level messaging transaction requests or replies and to convert the high level messaging transaction structure into internet protocol (IP) packets.

22. The wireless device of claim **21**, wherein the logic is further operative to convert single-byte based monitor read or write commands into multi-byte monitor read or write requests.

23. The wireless device of claim **17**, wherein the logic comprises a central processing unit (CPU), and further comprising a graphics processing unit (GPU) operatively coupled to the CPU and configured to provide image data to the wireless transceiver, and wherein the wireless transceiver is operative to communicate the image data and the IP formatted monitor control commands to a wireless transceiver associated with a monitor.

24. The wireless device of claim **17**, wherein the wireless device comprises a dongle including at least one of a universal serial bus (USB) interface, a DisplayPort (DP) interface, a high definition multimedia interface (HDMI), a video graphics array (VGA) interface, and a digital video interface (DVI).

25. The wireless device of claim **17**, wherein the wireless transceiver is a short range wireless transceiver.

26. A wireless device comprising:

a wireless transceiver;

logic, operatively coupled to the wireless transceiver, operative to translate internet protocol (IP) formatted monitor control commands from an IP format to produce monitor control commands intended for communication over a multi-wire bidirectional bus and to control operation of a monitor based on the produced monitor control commands intended for communication over the multi-wire bidirectional bus.

27. The wireless device of claim **26**, wherein the multi-wire bidirectional bus comprises an inter-integrated circuit bus.

28. The wireless device of claim **26**, wherein the logic is operative to generate a plurality of low level messaging transaction requests or replies from a high level messaging transaction structure.

29. The wireless device of claim **28**, wherein the logic is operative convert multi-byte monitor read or write requests into single-byte based monitor read or write commands.

30. The wireless device of claim **26**, wherein the logic is further operative to translate monitor capability data intended for communication over a multi-wire bidirectional bus to an internet protocol (IP) format to produce IP formatted monitor capability data and to communicate the produced IP formatted monitor capability data to an IP port dedicated for communicating IP formatted monitor capability data.

31. The wireless device of claim **26**, further comprising a monitor operatively coupled to the logic and operative to display image data received with the wireless transceiver.

32. The wireless device of claim **26**, wherein the logic comprises a microprocessor, and wherein the wireless transceiver is operative to receive the IP formatted monitor control commands from a wireless transceiver associated with a remote display source.

33. The wireless device of claim **26**, wherein the wireless device comprises a dongle including at least one of a universal serial bus (USB) interface, a DisplayPort (DP) interface, a high definition multimedia interface (HDMI), a video graphics array (VGA) interface, and a digital video interface (DVI).

34. The wireless device of claim **26**, wherein the wireless transceiver is a short range wireless transceiver.

35. A wireless display comprising:

a monitor;

a controller operatively coupled to the monitor and operative to provide image data to the monitor for display on the monitor; and

a wireless device, operatively coupled to the controller, comprising a wireless transceiver and logic, the logic being operative to translate internet protocol (IP) formatted monitor control commands from an IP format to produce monitor control commands intended for communication over a multi-wire bidirectional bus, the controller controlling operation of the monitor based on the produced monitor control commands intended for communication over the multi-wire bidirectional bus.

36. The wireless display of claim **35**, further comprising a display interface operatively coupled to the wireless device and the controller, the display interface including a multi-wire bidirectional bus, the logic of the wireless device being operative to communicate the produced monitor control commands to the controller over the multi-wire bidirectional bus of the display interface.

37. The wireless display of claim **36**, wherein the multi-wire bidirectional bus comprises an inter-integrated circuit bus.

38. The wireless display of claim **35**, wherein the produced monitor control commands are operative to control at least one of display color, display geometry, and image display parameters of the monitor.

39. The wireless display of claim **38**, wherein the image display parameters include at least one of image orientation, zoom, brightness, contrast, gamma, focus, backlight control, and white point.

40. The wireless display of claim **35**, wherein the logic of the wireless device is operative to convert a high level messaging transaction structure into a plurality of low level messaging transaction requests, wherein the high level messaging transaction structure comprises multi-byte monitor read or write requests and the low level messaging transaction requests comprise single-byte based monitor read or write commands.

41. The wireless display of claim **35**, wherein the logic of the wireless device is further operative to translate monitor capability data intended for communication over a multi-wire bidirectional bus to an internet protocol (IP) format to produce IP formatted monitor capability data and to communicate the produced IP formatted monitor capability data to an IP port dedicated for communicating IP formatted monitor capability data.

42. A display system comprising:

a display source comprising:

a short range wireless transceiver, and

logic, operatively coupled to the short range wireless transceiver, operative to translate monitor control commands to an internet protocol (IP) format to produce IP formatted monitor control commands and to communicate the IP formatted monitor control commands to an IP port dedicated for communicating IP formatted monitor control commands; and

a wireless display comprising:

a monitor,

a controller operatively coupled to the monitor for controlling the monitor, and

a wireless device, operatively coupled to the controller, comprising a short range wireless transceiver and logic, the short range wireless transceiver of the wireless device being operative to receive the IP formatted monitor control commands from the short range wireless transceiver of the display source, the logic of the wireless device being operative to translate the received IP formatted monitor control commands from the IP format to produce monitor control commands intended for communication over a multi-wire bidirectional bus, the controller controlling operation of the monitor based on the produced monitor control commands intended for communication over the multi-wire bidirectional bus.

43. The display system of claim **42**, wherein the display source further comprises an image provider operative to provide monitor control commands intended for communication over a multi-wire bidirectional bus to the logic of the display source, the image provider being further operative to provide image data to the display device for display on the monitor.

44. The display system of claim **43**, wherein the image provider communicates the image data over the short range wireless transceiver of the display source.

45. The display system of claim **43**, wherein the image provider comprises at least one processor.

46. The display system of claim **42**, wherein the IP port dedicated for communicating IP formatted monitor control commands is an IP port associated with the wireless device of the wireless display.

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