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Seamless Role Switch Of Two True Wireless Earbuds Which Is Using Relay Solution

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Abstract

A solution is provided to make the role switch of fully wireless earbuds in relay format "seamless." As such, no audio glitch is perceptible when the role switch occurs. When role switch occurs, the first accessory sends all wireless communication profile information to the second accessory. The second accessory can then reconstruct all the profiles used between the first accessory and the host. The first accessory and second accessory will negotiate the exact timing of switching roles, then the first accessory makes sure all the existing audio buffer contents are synchronized with the second accessory. Then role switch occurs, and the first accessory becomes the slave while the second accessory becomes the master. The first and second devices now use the third ACL link for data transfer, instead of the second ACL link. By using the third ACL link, the first and second accessories do not need to do a traditional Bluetooth role switch, thereby avoiding a possibility of audio glitches of approximately 300ms.

Background

Full wireless earbuds are two earbuds that connect to each other wirelessly. Typically such full wireless earbuds follow a relay format or a sniff format. In the relay format, one earbud serves a master role, and the other earbud serves a slave role. The master earbud receives audio from a host, e.g., a mobile phone or other audio playback device, then relays the audio to the slave earbud.

Role switch between two earbuds happens when the roles of earbuds change. For example, for relay format earbuds, the master becomes the slave, and the slave becomes the master. For sniff format earbuds, the primary earbud becomes secondary, and the secondary earbud becomes primary. Role switch can happen if, for example, the slave earbud has better received signal strength, if the master earbud is running on lower battery than the slave, if the master earbud loses connection with host, etc.

Wireless earbuds in relay format typically have a first asynchronous connection-less (ACL) link between the host device and the master earbud, where the master earbud is a Bluetooth slave in this ACL link. A second ACL link exists between the master earbud and the slave earbud. In this second ACL, the master earbud is the Bluetooth master, and the slave earbud is the Bluetooth slave. In this format, it is very difficult to achieve seamless role switch. For example, most, if not all, profiles in the ACL between the master earbud and the host device need to be transferred to the slave earbud silently, so that after role switch the new master earbud can continue receiving audio packets. Further, a Bluetooth role switch is also required as the old master earbud becomes the new slave earbud, while the old slave earbud becomes new master earbud, because the master earbud should also be the Bluetooth master to be efficient at Bluetooth transmission.

Overview

The present disclosure provides for perceptible continuity of music streaming when role switch occurs in a fully wireless pair of accessories, such as earbuds. By providing for seamless role switch, user experience is improved. For example, audio content is continually received without a glitch despite the role switch. Moreover, battery life may be extended by switching the role of master, which typically consumes more power, from a first device to a second device.

A system designed to achieve the "seamless" role switch includes a host device, a first accessory serving as the master, and a second accessory serving as a slave. A first ACL link is provided between the host device and the first accessory, wherein the first accessory is a Bluetooth slave relative to the host device. While the examples herein relate to ACL links, it should be understood that the examples may also apply to other types of links, such as synchronous connection oriented (SCO) links. A second ACL link is provided between the first accessory and the second accessory, wherein the first accessory is a master in this second ACL link and the second accessory is a slave. A third ACL link is also provided between the first accessory and the second accessory, wherein the first accessory is the slave for this second ACL link and the second accessory is the master. As a default mode of operation, data is relayed between the first and second accessories using the second ACL link.

When role switch occurs, the first accessory sends all wireless communication profile information to the second accessory. This ensures that the second accessory, when serving as the new master, can continue receiving audio quickly. The second accessory can then reconstruct all the profiles used between the first accessory and the host. However, the second accessory does not yet communicate directly with the host. The first accessory and second accessory will negotiate the exact timing of switching roles, then the first accessory makes sure all the existing audio buffer contents are synchronized with the second accessory. Then role switch occurs, and the first accessory becomes the slave while the second accessory becomes the master. As such, the second accessory communicates directly with the host, while the first accessory does not send any packets to the host. The first and second devices now use the third ACL link for data transfer, instead of the second ACL link. By using the third ACL link, the first and second accessories do not need to do a traditional Bluetooth role switch, thereby avoiding a possibility of audio glitches of approximately 300ms. In other examples, rather than using the third ACL link, the first and second accessories may use only one ACL link between them, and use Bluetooth sniff mode to configure the new master to work as slave to two Bluetooth master devices (host device and old master earbud). This requires accurate Bluetooth schedule synchronization between earbuds, but does not require Bluetooth role switch.

If a need for role switch happens again, the second accessory will send wireless communication profile info so that the first accessory can reconstruct the profiles. The second accessory will also send the audio buffer contents. The first and second accessories can then switch roles again, such that the first accessory returns to being the master, the second accessory returns to being the slave, and the devices again communicate over the second ACL link.

Example Systems

Fig. 1 illustrates an example system 100 including a host device 105 communicatively coupled to master accessor device 110. The master accessory device 110 may be one of a pair of accessory devices, such as earbuds, wireless speakers, etc. As such, the master device 110 is further communicatively coupled to slave accessory device 120. While only one slave device 120 is shown in Fig. 1, it should be understood that multiple slave devices may be communicatively coupled with the master device 110.

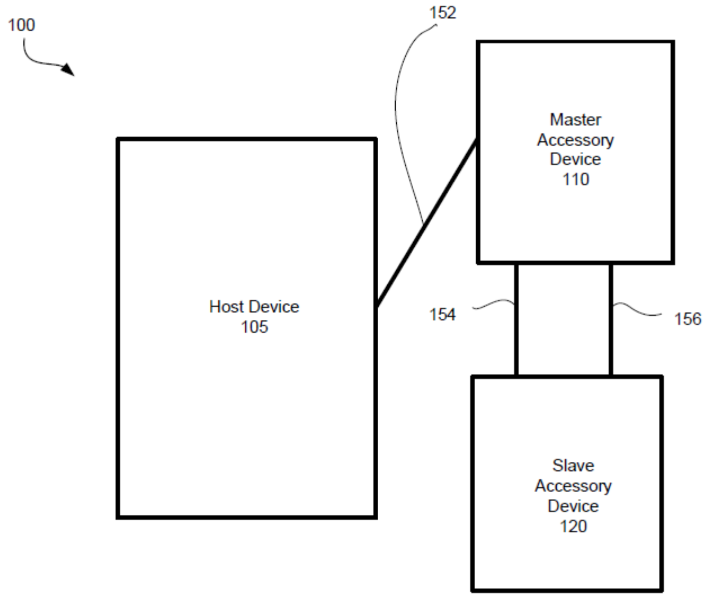

Fig. 1

The connection between the devices 105, 110, 120 may be, for example, short range wireless pairing, such as Bluetooth, near field magnetic induction communication (NFMI), etc. For example, host device 105 may be coupled to master device 110 via a first ACL link 152. The master device 110 may be coupled to slave device 120 via a second ACL link 154, as well as a third ACL link 156. The third ACL link 156 may serve as an alternate connection to the second ACL link 154. For example, while both links 154, 156 are maintained at a same time, only one link is used at a time depending on an operation mode of the devices 110, 120. When the master device 110 is serving as master, the second ACL link 154 may be used. However, when the master device 110 and the slave device 120 switch roles, the devices may use the third ACL link 156. While the example above describes the links between devices as ACL links, it should be understood that other types of links may alternatively or additionally be implemented.

Fig. 2 illustrates an example of the system of Fig. 1, wherein the host device is a mobile phone 205, the master accessory is a first earbud 210, and the slave accessory is a second earbud 220. First ACL link 252 exists between the phone 205 and the first earbud 210, while second and third ACL links 254, 256 exist between the first earbud 210 and the second earbud 220.

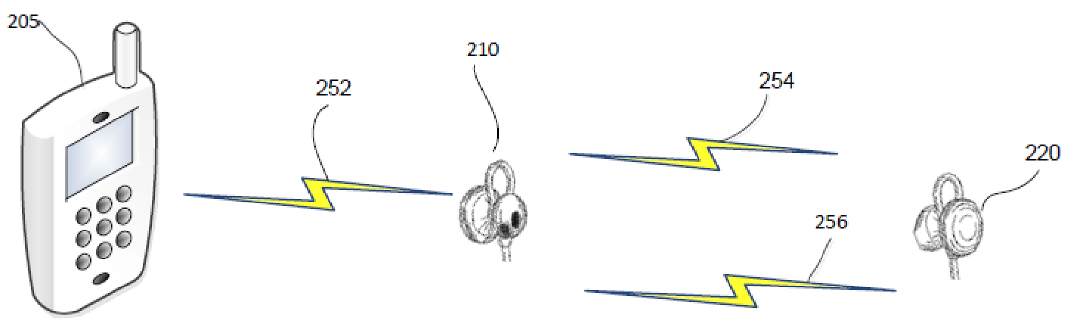

Fig. 2

While the host device in this example is illustrated as a mobile phone, it should be understood that the host device may be any of various types of devices adapted to transmit audio signals. For example, the host device may be a tablet, smart watch, game system, music player, laptop, personal digital assistant device, or any other computing device. Similarly, the first and second accessories, while here shown as earbuds 210, 220, may in other examples be any combination of speakers or other audio devices, video output displays, etc. The first and second accessories may be paired during a time of manufacture, or may be sold separately and paired later by a user.

Figs. 3A-D illustrate the system 100 of Fig. 1 undergoing a role switch. As shown in Fig. 3A, the master accessory 110 includes wireless communication protocol profiles 112, such as Bluetooth profiles. Examples of such profiles include audio/video remote control profile (ADVRP), hands free profile (HFP), advanced audio distribution profile (A2DP), attribute profile (ATT), device ID profile (DIP), proximity profile (PXP), synchronization profile (SYNCH), radio frequency communication (RFCOMM), Bluetooth low energy (BLE), or the like. The profiles 112 may dictate how the master device 110 operates. For example, the profiles may contain information regarding dependencies on other formats, suggested user interface formats, parts of a protocol stack used by the profile, etc. In some examples, the profiles may determine how the master device 110 communicates with the host device 105. By way of example only, one or more of the profiles may be used to establish the first ACL link 152. In other examples, the profiles may define how audio is streamed from the host device 105 to the master device 110, and/or from the master device 110 to the slave device 120.

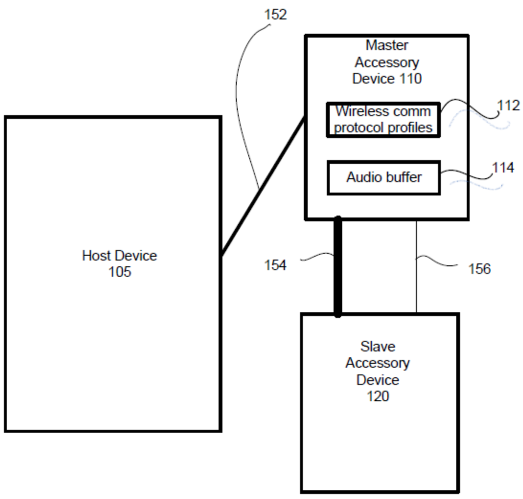

Fig. 3A

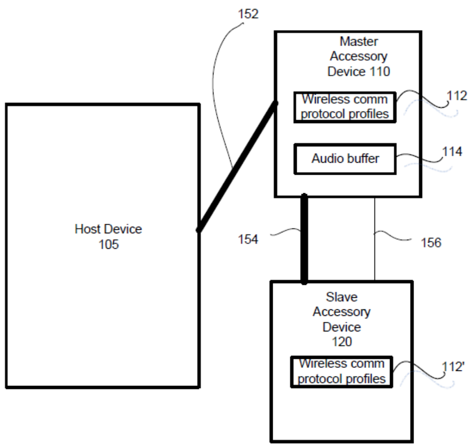

Fig. 3B

The master device 110 further includes an audio buffer 114, which may temporarily store audio packets received from the host device 105 for playback by the master device 110 and/or the slave device 120. Depending on the type of master and slave devices used and the types of functionality, other types of buffers may additionally or alternatively be present in the master device 110. For example, the master device 110 may include a buffer of video packets, etc.

The master device 110 communicates with the slave device 120 over the second ACL link 154. For example, the master device 110 sends data, audio, control, or other types of packets to the slave device 120 over the ACL link 154.

As shown in Fig. 3B, the master device 110 also sends the wireless communication profiles 112 to the slave device 120 over the ACL link 154. The slave device 120 may store the profiles, shown as profiles 112'. The slave device 120 may use the profiles 112' to silently take over the link 152 between the host device 105 and the master 110. For example, the slave re-constructs the profiles and links inside the slave device 120. However, the slave 120 may hold off on transmitting or receiving packets over the firstACL link 152 until further actions take place. By way of example, the slave 120 may wait until it can synch up its audio buffer with that of the master device, as shown in Fig. 3C.

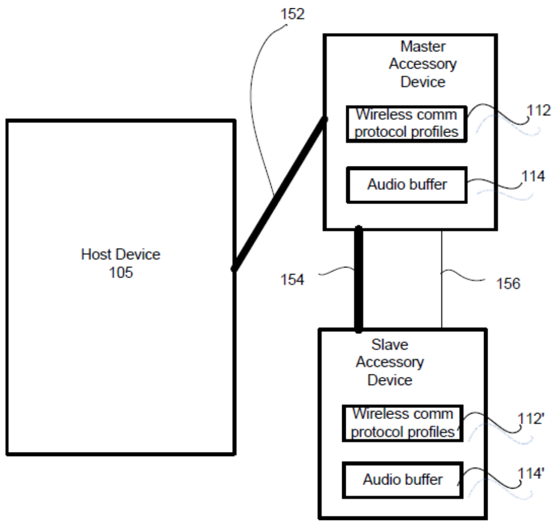

Fig. 3C

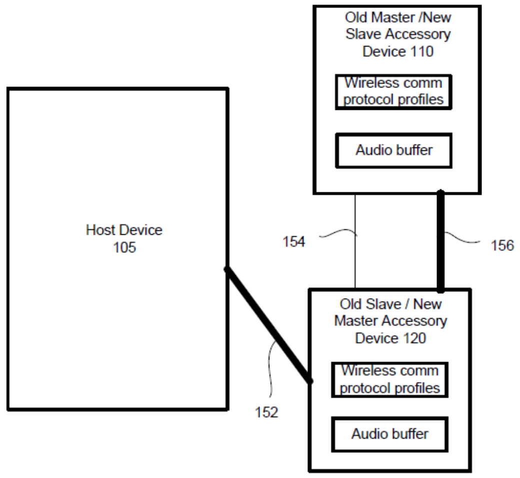

Fig. 3D

Fig. 3C illustrates the master device 110 synching its audio buffer 114 with slave device 120. For example, any audio packets recently received by the master device 110, and stored in the buffer 114, may be transmitted to the slave device 120 and stored in the slave buffer 114'. In this regard, the slave device 120 has the same buffer contents, and can begin playback of audio without delay upon switching to the role of master. While only audio packets in an audio buffer are shown in this example, it should be understood that other types of buffers, such as video or image buffers, may also be synced.

Fig. 3D illustrates the role switch of the device 110, 120. As shown, device 110 that was previously serving as master has become the slave, while device 120 that was previously the slave has become the master. Old slave/new master device 120 may now communicate directly with the host device 105 over the firstACL link 152, and playback audio without a noticeable glitch. For example, the old master will stop receiving/sending packets from/to host device 105, while the new master 120 will start receiving/sending packets from/to host device 105. During the whole process shown in Figs. 3A-3D, the host device 105 does not detect any change in the ACL link 152.

Fig. 4 illustrates an example electronic device 400 adapted to switch master/slave roles with a paired wireless device. The electronic device 400 may be, for example, a wireless accessory, such as an earbud, a speaker, a display, etc. The electronic device 400 may include one or more processors 430, one or more memories 420, as well as other components. For example, the computing device 400 may include one or more sensors 440, wireless pairing interface 445, and a battery 450.

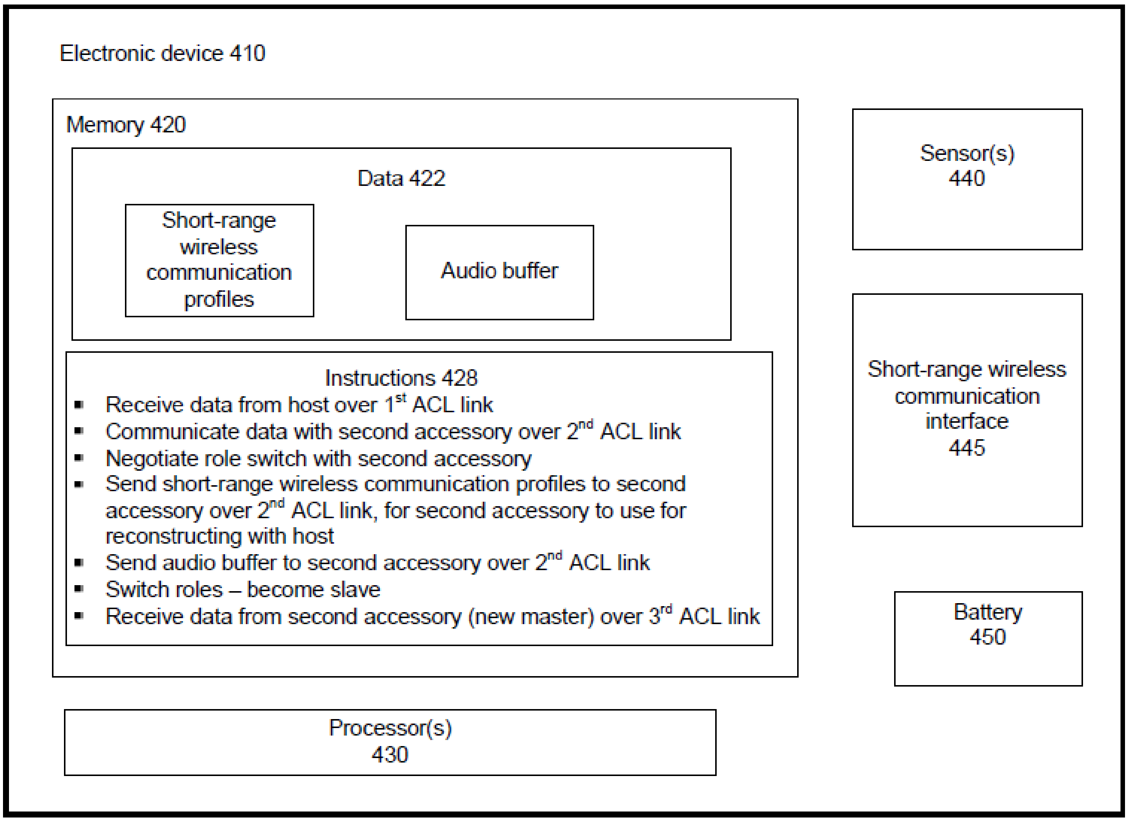

Fig. 4

The memory 420 may store information accessible by the one or more processors 430, including data 422 instructions 428 that may be executed or otherwise used by the one or more processors 430. For example, memory 420 may be of any type capable of storing information accessible by the processor(s), including a computing device-readable medium, or other medium that stores data that may be read with the aid of an electronic device, such as a volatile memory, non-volatile as well as other write-capable and read-only memories. By way of example only, memory 420 may be a static random-access memory (SRAM) configured to provide fast lookups.

The data 422 may be retrieved, stored or modified by the one or more processors 430 in accordance with the instructions 428. For instance, data 422 may include short range wireless communication profiles, such as Bluetooth profiles. The data 422 may further include buffered packets, such as an audio buffer with packets received from a host device. Although the claimed subject matter is not limited by any particular data structure, the data may be stored in computing device registers, in a relational database as a table having a plurality of different fields and records, XML documents or flat files. The data may also be formatted in any computing device-readable format.

The instructions 428 may be any set of instructions to be executed directly (such as machine code) or indirectly (such as scripts) by the one or more processors 430. For example, the instructions may be stored as computing device code on the computing device-readable medium. In that regard, the terms "instructions" and "programs" may be used interchangeably herein. The instructions may be stored in object code format for direct processing by the processor, or in any other computing device language including scripts or collections of independent source code modules that are interpreted on demand or compiled in advance. Functions, methods and routines of the instructions are explained in more detail below.

The one or more processors 430 may be microprocessors, logic circuitry (e.g., logic gates, flip-flops, etc.) hard-wired into the device 400 itself, or may be a dedicated application specific integrated circuit (ASIC). It should be understood that the one or more processors 430 are not limited to hard-wired logic circuitry, but may also include any commercially available processing unit, or any hardware-based processors, such as a field programmable gate array (FPGA). In some examples, the one or more processors 430 may include a state machine. The processors 430 may be configured to execute the instruction 428 to, for example, perform a method such as described below in connection with Fig. 5.

The one or more sensors 440 may include any of a variety of mechanical or electromechanical sensors for detecting conditions relevant to a role switch. Such sensors may include, for example, an accelerometer, gyroscope, switch, light sensor, barometer, audio sensor (e.g., microphone), vibration sensor, heat sensor, radio frequency (RF) sensor, etc. In this regard, the device 400 may detect conditions indicating that the device should switch roles with its paired device. As one example, the sensors may detect received signal strength, and may compare the received signal strength to that of the paired device. The device 400 and its paired device may thus negotiate whether to switch roles. As another example, the sensors may detect other parameters, such as battery life, signal quality, movement, etc.

The short range wireless pairing interface 445 may be used to form connections with other devices, such as the paired device or a host device, such as a mobile phone providing the audio packets. The connection may be, for example, a Bluetooth connection or any other type of wireless pairing. By way of example only the connection may include an ACL link. The interface 445 may also be used to establish alternative communication links, such as an alternative communication link with the paired device, used for when the device 400 and the paired device switch roles.

Example Methods

Fig. 5 is a flow diagram illustrating an example method 500 of performing a seamless master/slave role switch with a wirelessly paired device. The method 500 may be executed by, for example, a first wireless accessory device communicatively coupled with a host device and a second wireless accessory device.

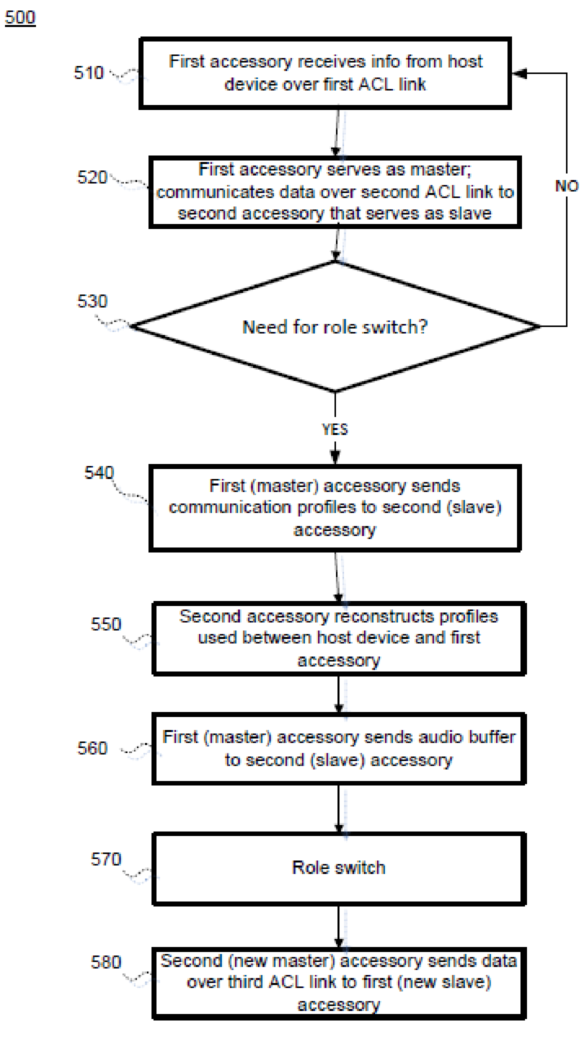

Fig. 5

In block 510, the first wireless accessory device receives packets from the host device over a first link, such as an ACL link. N block 520, the first wireless accessory device serves as master, relaying the received packets to the second wireless accessory device, which serves as slave.

In block 530, the first device determines whether to switch roles with the second device. Such determination may be made in response to a request from the second device, in response to detection of particular conditions, or for any other reason. If the device determines not to switch roles, the process 500 returns to block 510. However, if role switch is desired or necessary, the process 500 follows to block 540, where the first device sends communication profiles to the second device.

In block 550, the second device reconstructs a communication link with the host based on the received profiles. However, at this point the second device does not yet communicate over the reconstructed link. First, in block 560, the first device synchronizes with the second device, such as by providing its audio buffer. The second device copies this information so as to be able to readily playback information received from the host device once the second device becomes master.

In block 570 the first and second devices switch roles, such that the first device operates in a slave mode and the second device operates in a master mode. Accordingly, the first and second devices communicate over the third/alternate link.

Advantages

The systems and techniques described above are advantageous in that they provide for role switch with increased user experience. For example, fewer packets will be dropped, such that any glitch should be undetectable by a user. Moreover, because the wireless devices may switch roles more easily, battery life can be prolonged. For example, while operating in a master role typically consumes more battery power than operating in a slave mode, by switching roles more frequently the battery life of both devices may be fully used.