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GLOBAL SWITCH RESOURCE MANAGER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application Serial No. 60/776,584 filed February 24, 2006, the disclosure thereof incorporated by reference herein in its entirety.

BACKGROUND

[0002] The present invention relates generally to data communications. More particularly, the present invention relates to switch management.

SUMMARY

[0003] In general, in one aspect, the invention features an apparatus comprising: at least one input circuit to receive a plurality of data streams each comprising a plurality of packets of data, wherein at least one of the data streams has at least one performance requirement; at least one output circuit to transmit the data streams; a forwarding engine comprising a plurality of resources to transfer the packets of data from the at least one input circuit to the at least one output circuit; and a resource manager comprising a memory to store a data stream table, a performance requirements parser to determine the performance requirements for the at least one of the data streams, a data stream table manager to determine whether the performance requirements of the at least one of the data streams can be accepted based on entries in the data stream table, and to store the performance requirements for the at least one of the data streams as entries in the data stream table when the performance requirements for the at least one of the data streams are acceptable, and a resource programmer to program the resources according to the data stream table.

[0004] In general, in one aspect, the invention features an apparatus comprising: a plurality of resources to process packets of data in a plurality of data streams each comprising a plurality of the packets of data, wherein at least one of the data streams has at least one performance requirement; a memory to store a data stream table; a

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data stream table manager to determine whether the performance requirements of the at least one of the data streams can be accepted based on entries in the data stream table, and to store the performance requirements for the at least one of the data streams as entries in the data stream table when the performance requirements for the at least one of the data streams are acceptable; and a resource programmer to program the resources according to the data stream table.

[0005] In some embodiments, the data streams comprise at least one media stream. Some embodiments comprise at least one input circuit to receive the data streams; at least one output circuit to transmit the data streams; and a forwarding engine comprising at least one of the resources, wherein the at least one of the resources transfers the packets of data from the at least one input circuit to the at least one output circuit. Some embodiments comprise a performance requirements parser to determine the performance requirements for the at least one of the data streams. In some embodiments, the at least one input circuit receives a stream performance requirements packet representing the performance requirements for the at least one of the data streams; and the performance requirements parser determines the performance requirements for the at least one of the data streams based on the stream performance requirements packet. In some embodiments, to determine the performance requirements for the at least one of the data streams, the performance requirements parser parses the packets of data in the at least one of the data streams. Some embodiments comprise an alert circuit to generate an alert when the data stream table manager determines that the performance requirements for any of the data streams are unacceptable. Some embodiments comprise an alert circuit to generate an alert when one of the entries in the data stream table expires. Some embodiments comprise a command interface to receive commands, wherein the data stream table manager modifies the data stream table according to the commands. Some embodiments comprise a processor to generate the commands received by the command interface. In some embodiments, the performance requirements for the at least one of the data streams comprise at least one of: a bandwidth required by the one at least of the data streams; a burst size required by the one at least of the data streams; a latency required by the one at least of the data streams; and a jitter required by the one at least of the data streams. In some embodiments, the resources comprise at least one of: a buffer resource for the at least one input circuit; a rate-limiting

resource for the at least one input circuit; a buffer resource for the at least one output circuit; a scheduler resource for at least one of the at least one input circuit and the at least one output circuit; a rate-limiting resource for the at least one output circuit; and a buffer resource for the at least one output circuit. Some embodiments comprise a network device selected from the group consisting of a switch; and a router. Some embodiments comprise a wireless network device which is otherwise compliant with at least one standard selected from the group consisting of IEEE standards 802.11, 802.11a, 802.11b, 802.11g, 802.11n, 802.16, and 802.20.

[0006] In general, in one aspect, the invention features an apparatus comprising: a plurality of resource means for processing packets of data in a plurality of data streams each comprising a plurality of the packets of data, wherein at least one of the data streams has at least one performance requirement; means for storing a data stream table; data stream table manager means for determining whether the performance requirements of the at least one of the data streams can be accepted based on entries in the data stream table, and for storing the performance requirements for the at least one of the data streams as entries in the data stream table when the performance requirements for the at least one of the data streams are acceptable; and resource programmer means for programming the resources according to the data stream table.

[0007] In some embodiments, the data streams comprise at least one media stream. Some embodiments comprise at least one means for receiving the data streams; at least one means for transmitting the data streams; and means for forwarding comprising at least one of the resource means, wherein the at least one of the resource means transfers the packets of data from the at least one means for receiving to the at least one means for transmitting. Some embodiments comprise performance requirements parsing means for determining the performance requirements for the at least one of the data streams. In some embodiments, the at least one means for receiving receives a stream performance requirements packet representing the performance requirements for the at least one of the data streams; and the performance requirements parsing means determines the performance requirements for the at least one of the data streams based on the stream performance requirements packet. In some embodiments, to determine the performance requirements for the at least one of the data streams, the performance requirements parsing means parses the

packets of data in the at least one of the data streams. Some embodiments comprise an alert circuit to generate an alert when the data stream table manager determines that the performance requirements for any of the data streams are unacceptable. Some embodiments comprise an alert circuit to generate an alert when one of the entries in the data stream table expires. Some embodiments comprise a command interface to receive commands, wherein the data stream table manager modifies the data stream table according to the commands. Some embodiments comprise a processor to generate the commands received by the command interface. In some embodiments, the performance requirements for the at least one of the data streams comprise at least one of: a bandwidth required by the one at least of the data streams; a burst size required by the one at least of the data streams; a latency required by the one at least of the data streams; and a jitter required by the one at least of the data streams. In some embodiments, the resources comprise at least one of: a buffer resource for the at least one means for receiving; a rate-limiting resource for the at least one means for receiving; a buffer resource for the at least one means for transmitting; a scheduler resource for at least one of the at least one means for receiving and the at least one means for transmitting; a rate-limiting resource for the at least one means for transmitting; and a buffer resource for the at least one means for transmitting. Some embodiments comprise a network device selected from the group consisting of: a switch; and a router. Some embodiments comprise a wireless network device which is otherwise compliant with at least one standard selected from the group consisting of IEEE standards 802.11, 802.11a, 802.11b, 802.11g, 802.11n, 802.16, and 802.20.

[0008] In general, in one aspect, the invention features a method comprising: processing a plurality of data streams using a plurality of resources, wherein each of the data streams comprises a plurality of packets of data, and wherein at least one of the data streams has at least one performance requirement; storing a data stream table; determining whether the performance requirements for the at least one of the data streams can be accepted based on the entries in the data stream table; storing the performance requirements for the at least one of the data streams in the data stream table when the performance requirements for the at least one of the data streams are acceptable; and programming the resources according to the data stream table.

[0009] In some embodiments, the data streams comprise at least one media stream. Some embodiments comprise receiving the plurality of data streams into at least one

input circuit; transmitting the data streams from at least one output circuit; and transferring the packets of data from the at least one input circuit to the at least one output circuit using at least one of the resources. Some embodiments comprise determining the performance requirements for the at least one of the data streams. Some embodiments comprise receiving a stream performance requirements packet representing the performance requirements for the at least one of the data streams; and determining the performance requirements for the at least one of the data streams based on the stream performance requirements packet. In some embodiments, determining the performance requirements for the at least one of the data streams comprises: parsing the packets of data in the one of the data streams. Some embodiments comprise generating an alert when the performance requirements for any of the data streams are unacceptable. Some embodiments comprise generating an alert when one of the entries in the data stream table expires. Some embodiments comprise receiving commands; and modifying the data stream table according to the commands. Some embodiments comprise generating the commands. In some embodiments, the performance requirements for the at least one of the data streams comprise at least one of: a bandwidth required by the at least one of the data streams; a burst size required by the at least one of the data streams; a latency required by the at least one of the data streams; and a jitter required by the at least one of the data streams. In some embodiments, the resources comprise at least one of: a buffer resource; a rate-limiting resource; and a buffer resource.

[0010] In general, in one aspect, the invention features a computer program comprising: identifying a plurality of data streams, wherein each of the data streams comprises a plurality of packets of data, and wherein at least one of the data streams has at least one performance requirement; storing a data stream table; determining whether the performance requirements for the at least one of the data streams can be accepted based on the entries in the data stream table; storing the performance requirements for the at least one of the data streams in the data stream table when the performance requirements for the at least one of the data streams are acceptable; and programming a plurality of resources for processing the at least one data stream according to the data stream table.

[0011] In some embodiments, the data streams comprise at least one media stream. Some embodiments comprise determining the performance requirements for the at

least one of the data streams. Some embodiments comprise receiving a stream performance requirements packet representing the performance requirements for the at least one of the data streams; and determining the performance requirements for the at least one of the data streams based on the stream performance requirements packet. In some embodiments, determining the performance requirements for the at least one of the data streams comprises: parsing the packets of data in the one of the data streams. Some embodiments comprise generating an alert when the performance requirements for any of the data streams are unacceptable. Some embodiments comprise generating an alert when one of the entries in the data stream table expires. Some embodiments comprise receiving commands; and modifying the data stream table according to the commands. Some embodiments comprise generating the commands. In some embodiments, the performance requirements for the at least one of the data streams comprise at least one of: a bandwidth required by the at least one of the data streams; a burst size required by the at least one of the data streams; a latency required by the at least one of the data streams; and a jitter required by the at least one of the data streams. In some embodiments, the resources comprise at least one of: a buffer resource; a rate-limiting resource; and a scheduler resource.

[0012] The details of one or more implementations are set forth in the accompanying drawings and the description below. Other features will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

[0013] FIG. 1 shows a data communication system according to a preferred embodiment of the present invention.

[0014] FIG. 2 shows detail of forwarding engine according to a preferred embodiment of the present invention.

[0015] FIG. 3 shows a process for the network switch of FIG. 1 according to a preferred embodiment of the present invention.

[0016] FIGS. 4A-4E show various exemplary implementations of the present invention.

[0017] The leading digit(s) of each reference numeral used in this specification indicates the number of the drawing in which the reference numeral first appears.

DETAILED DESCRIPTION

[0018] Currently in present-day switches resources are managed at an individual resource level. The disadvantage of this approach is that a packet of data that is assigned one or more switch resources could still be discarded within the switch due to the lack of another resource. This situation makes it difficult to offer any quality of treatment guarantees for data streams.

[0019] Embodiments of the present invention provide global switch resource managers to globally manage the resources of network switches according to performance requirements of the data streams switched by the switch. More generally, embodiments of the present invention provide resource managers to globally manage the resources of an apparatus processing multiple data streams according to performance requirements of the data streams. Embodiments of the present invention are especially useful for media streams that require resource guarantees, such as video and audio streams. However, embodiments of the present invention can be used with any sort of data stream, such as more traditional data streams that require best effort with some prioritization. According to a preferred embodiment of the present invention, a global switch resource manager determines the performance requirements of each data stream, and if the performance requirements are acceptable, records the performance requirements and allocates the resources of the switch to the data stream accordingly.

[0020] FIG. 1 shows a data communication system 100 according to a preferred embodiment of the present invention. Data communication system 100 comprises a network switch 102 in communication with a network 140. Network 140 can comprise a local-area network (LAN), which can be a wired LAN, a wireless LAN (WLAN), or the like. In some embodiments, network switch 102 is implemented within network devices such as routers and the like. In wireless embodiments, network switch 102 is preferably otherwise compliant with at least one of IEEE standards 802.11, 802.11a, 802.11b, 802.11g, 802.11n, 802.16, and 802.20.

[0021] Network switch 102 comprises at least one input circuit 104 to receive a plurality of data streams each comprising a plurality of packets of data, at least one output circuit 106 to transmit the data streams, a forwarding engine 108 comprising a plurality of resources 110 to transfer the packets of data from input circuit(s) 104 to output circuit(s) 106, and a global resource manager 112 to program the resources 110 according to performance requirements for each of the data streams.

[0022] Global resource manager 112 comprises a performance requirements parser 114 to determine the performance requirements for each of the data streams, a memory 116 to store a data stream table 118, a data stream table manager 120 to determine whether the performance requirements for each data stream can be accepted based on the entries in data stream table 118, and when the performance requirements for a data stream are acceptable, to store the performance requirements for the data stream in data stream table 118, and a resource programmer 122 to program resources 110 according to data stream table 118. Network switch 102 also preferably comprises a forwarding database 124 which is used by forwarding engine 108 to transfer the packets. Global resource manager 112 optionally comprises an alert circuit 126 to generate an alert when data stream table manager 120 determines that the performance requirements for any of the data streams are unacceptable, and a processor interface 128 to receive processor commands to modify data stream table 118. Global resource manager 112 optionally comprises a processor 130 to generate the processor commands.

[0023] FIG. 2 shows detail of resources 110 according to a preferred embodiment of the present invention. As stated above, forwarding engine 108 comprises a plurality of resources 110 to transfer the packets of data from input circuit(s) 104 to output circuit(s) 106. While resources 110 of forwarding engine 108 are described in the context of an output-queued switch, other resources can be used in other types of switches, as will be apparent to one skilled in the relevant arts after reading this description. Referring to FIG. 2, resources 110 comprise ingress buffer resources 202 and ingress rate-limiting resources 204 for input circuit(s) 104, queue resources 206 for output circuit(s) 106, output port scheduler resources 208 and output queue scheduler resources 210 for output circuit(s) 106, and egress buffer resources 212 and egress rate-limiting resources 214 for output circuit(s) 106. Buffer and queue resources 202, 206, and 212 can comprise, for example, an allocation in a buffer or

queue, an allocation of buffer or queue pointers, and the like. Scheduler and rate-limiting resources 204, 208, 210, and 214 can comprise, for example, an allocation of a priority in a priority scheme, an allocation of time slots in a schedule, and the like.

[0024] FIG. 3 shows a process 300 for network switch 102 of FIG. 1 according to a preferred embodiment of the present invention. Performance requirements parser 114 determines the performance requirements for the data streams to be handled by network switch 102 (step 302). In some cases, the requirements for a data stream are conveyed by a special stream performance requirements packet representing the performance requirements for the data stream. In such cases, performance requirements parser 114 preferably determines the performance requirements for each data stream based on the respective stream performance requirements packet. In other cases, the requirements for a data stream can be obtained by monitoring setup packets for the data stream, for example with asynchronous transfer mode (ATM) data streams, frame relay data streams, and the like. In such cases, performance requirements parser 114 preferably determines the performance requirements for the data stream based on the respective setup packets.

[0025] Data stream table manager 120 reads data stream table 118 to determine whether the data stream is a new stream, or instead a data stream already stored in data stream table 118 (step 304). If the data stream already has an entry in data stream table 118, data stream table manager 120 optionally refreshes the entry (step 306). For example, some embodiments employ aging mechanisms to remove data streams from data stream table 118 after predetermined intervals unless refreshed.

[0026] But when the data stream is a new stream, data stream table manager 120 determines whether the performance requirements of the data stream can be accepted based on the entries in data stream table 118 (step 308). When the performance requirements for the data stream are unacceptable, data stream table manager 120 optionally blocks the data stream (step 310). For example, data stream table manager 120 modifies forwarding database 124 so that forwarding engine 108 simply drops all of the packets in the data stream. In some embodiments, alert circuit 126 generates an alert indicating that the performance requirements for the data stream are unacceptable (step 312). For example, the alert can be sent to a system administrator, an application, a higher-level protocol, and the like. In embodiments employing aging

mechanisms for the entries in data stream table 118, alert circuit 126 can generate an alert when one of the entries in data stream table 118 expires.

[0027] But when the performance requirements for the data stream are acceptable, data stream table manager 120 stores the performance requirements for the data stream in data stream table 118 (step 314). The performance requirements for a data stream can comprise a bandwidth required by the data stream, a burst size required by the data stream, a latency required by the data stream, a jitter required by the data stream, and the like.

[0028] The bandwidth requirement indicates the bandwidth needed for the data stream. In some embodiments the bandwidth requirement can range from 64kbps to 1Gbps, can be specified in 64kbps steps from 0 to 1Mbps, 1Mbps steps from 1Mbps to 100Mbps, and 10Mbps steps from 100Mbps to 1Gbps, and is stored in data stream table 118 as an 8-bit value.

[0029] The burst size requirement indicates the amount of burst that the application expects to be supported in the switch hardware. In some embodiments the burst size requirement can range from 64KBytes to 16MBytes in steps of 64Kbytes, and is stored in data stream table 118 as an 8-bit value.

[0030] The latency requirement indicates the amount of latency the user application is sensitive to. For example video/audio applications could be more sensitive to latency than data applications. In some embodiments the latency requirement can range from 10μs to 2000μs, and is stored in data stream table 118 as a 12-bit value.

[0031] The jitter requirement indicates the amount of jitter the user application is sensitive to. In some embodiments the jitter requirement can range from 10μs to 2000μs, and is stored in data stream table 118 as an 8-bit value.

[0032] Of course other embodiments can handle these and other sorts of requirements in the same or different combinations, as will be apparent to one skilled in the relevant arts after reading this description.

[0033] Resource programmer 122 programs resources 110 according to data stream table 118 (step 316). For example, resource programmer 122 modifies the parameters for resources 110 according to techniques well-known in the relevant arts. The parameters for each resource 110 are generally stored in some sort of memory, such

as flip-flops, ternary content-addressable memory (TCAM), and the like. Resource programmer 122 modifies the stored parameters according to data stream table 118. For example, resource programmer 122 determines rate-limiting thresholds for each data stream based on the bandwidth and latency requirements stored for those data streams in data stream table 118, and writes those thresholds to the parameter memories for ingress rate-limiting resources 204 and egress rate-limiting resources 214.

[0034] Resource programmer 122 preferably is triggered to program resources 110 by data stream table manager 120 on each update of data stream table 118. But in some embodiments, resource programmer 122 can poll data stream table manager 120 to discover updates to data stream table 118.

[0035] Resources 110 preferably processes each of the packets in the data streams handled by network switch 102 according to the data stream to which the packets belong. Network switch 102 identifies the data stream to which each packet belongs as the packet is received, and assigns a corresponding data stream ID to the packet. For example, the data stream ID can be attached to the packet as a tag. Each resource 110 then identifies the data stream for each packet according to the tag, and processes the packet according to the parameters programmed for that data stream by resource programmer 122.

[0036] Some embodiments comprise a processor interface 128 to receive processor commands to modify data stream table 118, thereby allowing applications to establish requirements directly, and even before the corresponding data stream is set up. For example, a service provider can set up streams for customer in advance. According to these embodiments, processor interface 128 receives the processor commands, and data stream table manager 120 modifies data stream table 118 according to the processor commands. In some embodiments, processor 130 is external to network switch 102. In other embodiments, network switch 102 comprises processor 130.

[0037] In some embodiments, only a percentage of resources 110 are allocated to data streams which require resource guarantees. This ensures that the data streams which don't need resource guarantees, such as best-effort data streams, don't starve out completely. For example, the percentage of a resource that can be reserved is stored in a programmable register for that resource 110. For example, if only 75% of all frame

buffer pointers for queue resources 206 can be reserved then the register for queue resources 206 is programmed with the 75% number.

[0038] FIGS. 4A-4E show various exemplary implementations of the present invention. Referring now to FIG. 4A, the present invention can be implemented in a high definition television (HDTV) 412. The present invention may implement either or both signal processing and/or control circuits, which are generally identified in FIG. 4A at 413, a WLAN interface and/or mass data storage of the HDTV 412. The HDTV 412 receives HDTV input signals in either a wired or wireless format and generates HDTV output signals for a display 414. In some implementations, signal processing circuit and/or control circuit 413 and/or other circuits (not shown) of the HDTV 412 may process data, perform coding and/or encryption, perform calculations, format data and/or perform any other type of HDTV processing that may be required.

[0039] The HDTV 412 may communicate with mass data storage 415 that stores data in a nonvolatile manner such as optical and/or magnetic storage devices. The HDD may be a mini HDD that includes one or more platters having a diameter that is smaller than approximately 1.8". The HDTV 412 may be connected to memory 416 such as RAM, ROM, low latency nonvolatile memory such as flash memory and/or other suitable electronic data storage. The HDTV 412 also may support connections with a WLAN via a WLAN network interface 417.

[0040] Referring now to FIG. 4B, the present invention implements a control system of a vehicle 418, a WLAN interface and/or mass data storage of the vehicle control system. In some implementations, the present invention implements a powertrain control system 419 that receives inputs from one or more sensors such as temperature sensors, pressure sensors, rotational sensors, airflow sensors and/or any other suitable sensors and/or that generates one or more output control signals such as engine operating parameters, transmission operating parameters, and/or other control signals.

[0041] The present invention may also be implemented in other control systems 422 of the vehicle 418. The control system 422 may likewise receive signals from input sensors 423 and/or output control signals to one or more output devices 424. In some implementations, the control system 422 may be part of an anti-lock braking system (ABS), a navigation system, a telematics system, a vehicle telematics system, a lane

departure system, an adaptive cruise control system, a vehicle entertainment system such as a stereo, DVD, compact disc and the like. Still other implementations are contemplated.

[0042] The powertrain control system 419 may communicate with mass data storage 425 that stores data in a nonvolatile manner. The mass data storage 425 may include optical and/or magnetic storage devices for example hard disk drives HDD and/or DVDs. The HDD may be a mini HDD that includes one or more platters having a diameter that is smaller than approximately 1.8". The powertrain control system 419 may be connected to memory 426 such as RAM, ROM, low latency nonvolatile memory such as flash memory and/or other suitable electronic data storage. The powertrain control system 419 also may support connections with a WLAN via a WLAN network interface 427. The control system 422 may also include mass data storage, memory and/or a WLAN interface (all not shown).

[0043] Referring now to FIG. 4C, the present invention can be implemented in a cellular phone 428 that may include a cellular antenna 429. The present invention may implement either or both signal processing and/or control circuits, which are generally identified in FIG. 4C at 430, a WLAN interface and/or mass data storage of the cellular phone 428. In some implementations, the cellular phone 428 includes a microphone 431, an audio output 432 such as a speaker and/or audio output jack, a display 433 and/or an input device 434 such as a keypad, pointing device, voice actuation and/or other input device. The signal processing and/or control circuits 430 and/or other circuits (not shown) in the cellular phone 428 may process data, perform coding and/or encryption, perform calculations, format data and/or perform other cellular phone functions.

[0044] The cellular phone 428 may communicate with mass data storage 435 that stores data in a nonvolatile manner such as optical and/or magnetic storage devices for example hard disk drives HDD and/or DVDs. The HDD may be a mini HDD that includes one or more platters having a diameter that is smaller than approximately 1.8". The cellular phone 428 may be connected to memory 436 such as RAM, ROM, low latency nonvolatile memory such as flash memory and/or other suitable electronic data storage. The cellular phone 428 also may support connections with a WLAN via a WLAN network interface 437.

[0045] Referring now to FIG. 4D, the present invention can be implemented in a set top box 438. The present invention may implement either or both signal processing and/or control circuits, which are generally identified in FIG. 4D at 439, a WLAN interface and/or mass data storage of the set top box 438. The set top box 438 receives signals from a source such as a broadband source and outputs standard and/or high definition audio/video signals suitable for a display 440 such as a television and/or monitor and/or other video and/or audio output devices. The signal processing and/or control circuits 439 and/or other circuits (not shown) of the set top box 438 may process data, perform coding and/or encryption, perform calculations, format data and/or perform any other set top box function.

[0046] The set top box 438 may communicate with mass data storage 443 that stores data in a nonvolatile manner. The mass data storage 443 may include optical and/or magnetic storage devices for example hard disk drives HDD and/or DVDs. The HDD may be a mini HDD that includes one or more platters having a diameter that is smaller than approximately 1.8". The set top box 438 may be connected to memory 442 such as RAM, ROM, low latency nonvolatile memory such as flash memory and/or other suitable electronic data storage. The set top box 438 also may support connections with a WLAN via a WLAN network interface 443.

[0047] Referring now to FIG. 4E, the present invention can be implemented in a media player 444. The present invention may implement either or both signal processing and/or control circuits, which are generally identified in FIG. 4E at 445, a WLAN interface and/or mass data storage of the media player 444. In some implementations, the media player 444 includes a display 446 and/or a user input 447 such as a keypad, touchpad and the like. In some implementations, the media player 444 may employ a graphical user interface (GUI) that typically employs menus, drop down menus, icons and/or a point-and-click interface via the display 446 and/or user input 447. The media player 444 further includes an audio output 448 such as a speaker and/or audio output jack. The signal processing and/or control circuits 445 and/or other circuits (not shown) of the media player 444 may process data, perform coding and/or encryption, perform calculations, format data and/or perform any other media player function.

[0048] The media player 444 may communicate with mass data storage 449 that stores data such as compressed audio and/or video content in a nonvolatile manner. In some implementations, the compressed audio files include files that are compliant with MP3 format or other suitable compressed audio and/or video formats. The mass data storage may include optical and/or magnetic storage devices for example hard disk drives HDD and/or DVDs. The HDD may be a mini HDD that includes one or more platters having a diameter that is smaller than approximately 1.8". The media player 444 may be connected to memory 450 such as RAM, ROM, low latency nonvolatile memory such as flash memory and/or other suitable electronic data storage. The media player 444 also may support connections with a WLAN via a WLAN network interface 451. Still other implementations in addition to those described above are contemplated.

[0049] Embodiments of the invention can be implemented in digital electronic circuitry, or in computer hardware, firmware, software, or in combinations of them. Apparatus of the invention can be implemented in a computer program product tangibly embodied in a machine-readable storage device for execution by a programmable processor; and method steps of the invention can be performed by a programmable processor executing a program of instructions to perform functions of the invention by operating on input data and generating output. The invention can be implemented advantageously in one or more computer programs that are executable on a programmable system including at least one programmable processor coupled to receive data and instructions from, and to transmit data and instructions to, a data storage system, at least one input device, and at least one output device. Each computer program can be implemented in a high-level procedural or object-oriented programming language, or in assembly or machine language if desired; and in any case, the language can be a compiled or interpreted language. Suitable processors include, by way of example, both general and special purpose microprocessors. Generally, a processor will receive instructions and data from a read-only memory and/or a random access memory. Generally, a computer will include one or more mass storage devices for storing data files; such devices include magnetic disks, such as internal hard disks and removable disks; magneto-optical disks; and optical disks. Storage devices suitable for tangibly embodying computer program instructions and data include all forms of non-volatile memory, including by way of example

semiconductor memory devices, such as EPROM, EEPROM, and flash memory devices; magnetic disks such as internal hard disks and removable disks; magneto-optical disks; and CD-ROM disks. Any of the foregoing can be supplemented by, or incorporated in, ASICs (application-specific integrated circuits).

[0050] A number of implementations of the invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. Accordingly, other implementations are within the scope of the following claims.

WHAT IS CLAIMED IS:

1. An apparatus comprising:

at least one input circuit to receive a plurality of data streams each comprising a plurality of packets of data, wherein at least one of the data streams has at least one performance requirement;

at least one output circuit to transmit the data streams;

a forwarding engine comprising a plurality of resources to transfer the packets of data from the at least one input circuit to the at least one output circuit; and

a resource manager comprising

a memory to store a data stream table,

a performance requirements parser to determine the performance requirements for the at least one of the data streams,

a data stream table manager to determine whether the performance requirements of the at least one of the data streams can be accepted based on entries in the data stream table, and to store the performance requirements for the at least one of the data streams as entries in the data stream table when the performance requirements for the at least one of the data streams are acceptable, and

a resource programmer to program the resources according to the data stream table.

2. An apparatus comprising:

a plurality of resources to process packets of data in a plurality of data streams each comprising a plurality of the packets of data, wherein at least one of the data streams has at least one performance requirement;

a memory to store a data stream table;

a data stream table manager to determine whether the performance requirements of the at least one of the data streams can be accepted based on entries in the data stream table, and to store the performance requirements for the at least one of the data streams as entries in the data stream table when the performance requirements for the at least one of the data streams are acceptable; and

a resource programmer to program the resources according to the data stream table.

3. The apparatus of claim 2:

wherein the data streams comprise at least one media stream.

4. The apparatus of claim 2, further comprising:

at least one input circuit to receive the data streams;

at least one output circuit to transmit the data streams; and

a forwarding engine comprising at least one of the resources, wherein the at least one of the resources transfers the packets of data from the at least one input circuit to the at least one output circuit.

5. The apparatus of claim 2, further comprising:

a performance requirements parser to determine the performance requirements for the at least one of the data streams.

6. The apparatus of claim 5:

wherein the at least one input circuit receives a stream performance requirements packet representing the performance requirements for the at least one of the data streams; and

wherein the performance requirements parser determines the performance requirements for the at least one of the data streams based on the stream performance requirements packet.

7. The apparatus of claim 5:

wherein, to determine the performance requirements for the at least one of the data streams, the performance requirements parser parses the packets of data in the at least one of the data streams.

8. The apparatus of claim 2, further comprising:

an alert circuit to generate an alert when the data stream table manager determines that the performance requirements for any of the data streams are unacceptable.

9. The apparatus of claim 2, further comprising:

an alert circuit to generate an alert when one of the entries in the data stream table expires.

10. The apparatus of claim 2, further comprising:

a command interface to receive commands, wherein the data stream table manager modifies the data stream table according to the commands.

11. The apparatus of claim 10, further comprising:

a processor to generate the commands received by the command interface.

12. The apparatus of claim 2, wherein the performance requirements for the at least one of the data streams comprise at least one of:

a bandwidth required by the one at least of the data streams;

a burst size required by the one at least of the data streams;

a latency required by the one at least of the data streams; and

a jitter required by the one at least of the data streams.

13. The apparatus of claim 2, wherein the resources comprise at least one of:

a buffer resource for the at least one input circuit;

a rate-limiting resource for the at least one input circuit;

a buffer resource for the at least one output circuit;

a scheduler resource for at least one of the at least one input circuit and the at least one output circuit;

a rate-limiting resource for the at least one output circuit; and

a buffer resource for the at least one output circuit.

14. A network device comprising the apparatus of claim 2 and selected from the group consisting of:

a switch; and

a router.

15. A wireless network device comprising the apparatus of claim 2 which is otherwise compliant with at least one standard selected from the group consisting of IEEE standards 802.11, 802.11a, 802.11b, 802.11g, 802.11n, 802.16, and 802.20.

16. A method comprising:

processing a plurality of data streams using a plurality of resources, wherein each of the data streams comprises a plurality of packets of data, and wherein at least one of the data streams has at least one performance requirement;

storing a data stream table;

determining whether the performance requirements for the at least one of the data streams can be accepted based on the entries in the data stream table;

storing the performance requirements for the at least one of the data streams in the data stream table when the performance requirements for the at least one of the data streams are acceptable; and

programming the resources according to the data stream table.

17. The method of claim 16:

wherein the data streams comprise at least one media stream.

18. The method of claim 16, further comprising:

receiving the plurality of data streams into at least one input circuit;

transmitting the data streams from at least one output circuit; and

transferring the packets of data from the at least one input circuit to the at least one output circuit using at least one of the resources.

19. The method of claim 16, further comprising:

determining the performance requirements for the at least one of the data streams.

20. The method of claim 19, further comprising:

receiving a stream performance requirements packet representing the performance requirements for the at least one of the data streams; and

determining the performance requirements for the at least one of the data streams based on the stream performance requirements packet.

21. The method of claim 19, wherein determining the performance requirements for the at least one of the data streams comprises:

parsing the packets of data in the one of the data streams.

22. The method of claim 16, further comprising:

generating an alert when the performance requirements for any of the data streams are unacceptable.

23. The method of claim 16, further comprising:

generating an alert when one of the entries in the data stream table expires.

24. The method of claim 16, further comprising:

receiving commands; and

modifying the data stream table according to the commands.

25. The method of claim 24, further comprising:

generating the commands.

26. The method of claim 16, wherein the performance requirements for the at least one of the data streams comprise at least one of:

a bandwidth required by the at least one of the data streams;

a burst size required by the at least one of the data streams;

a latency required by the at least one of the data streams; and

a jitter required by the at least one of the data streams.

27. The method of claim 16, wherein the resources comprise at least one of:

a buffer resource;

a rate-limiting resource; and

a buffer resource.