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(54) INPUT/OUTPUT VIRTUALIZATION THROUGH OFFLOAD TECHNIQUES

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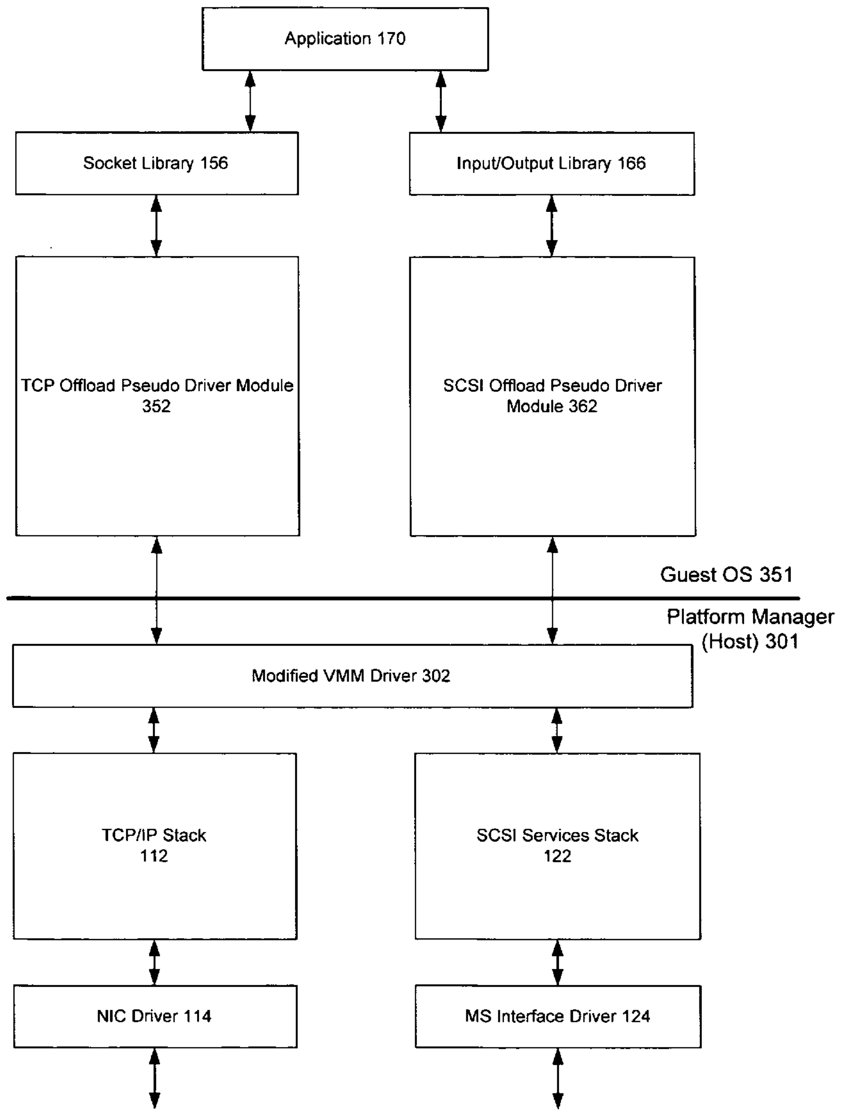
(57) **ABSTRACT**

A computer apparatus provides support multiple virtual computing machines. In accordance with one embodiment, the computer apparatus includes a platform manager, a virtual machine manager (VMM) driver of the platform manager, a TCP/IP stack of the platform manager, a guest operating system supported by the platform manager, and a TCP offload pseudo driver module of the guest operating system. The VMM driver is configured to transfer data between a top of the TCP/IP stack and the TCP offload pseudo driver module without changing a level of abstraction of the data. In accordance with another embodiment, the VMM driver is configured to transfer data between a top of a SCSI services stack and a SCSI offload pseudo driver module without changing a level of abstraction of the data. Other embodiments, aspects, and features are also disclosed.



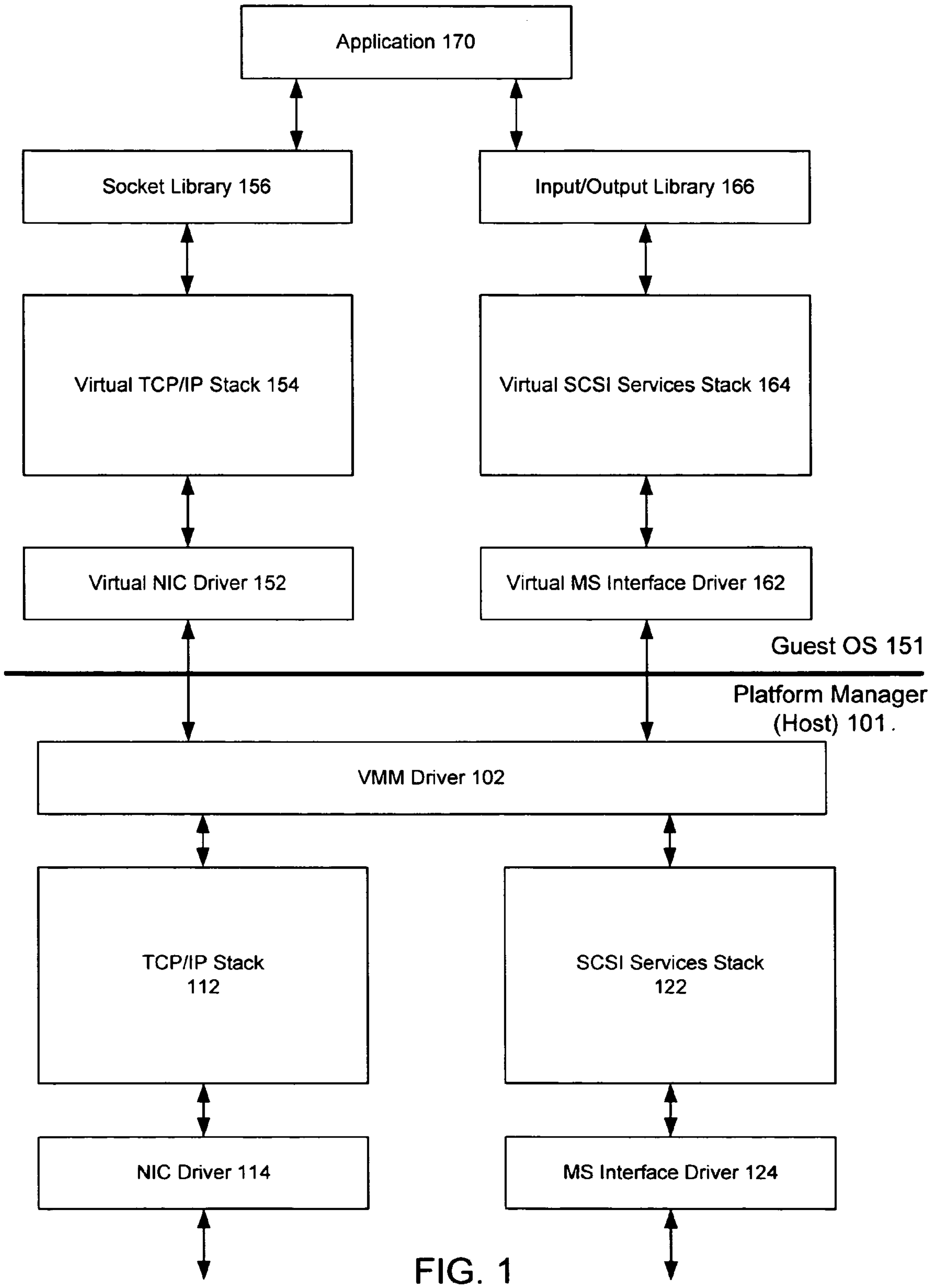


FIG. 1
(Conventional)

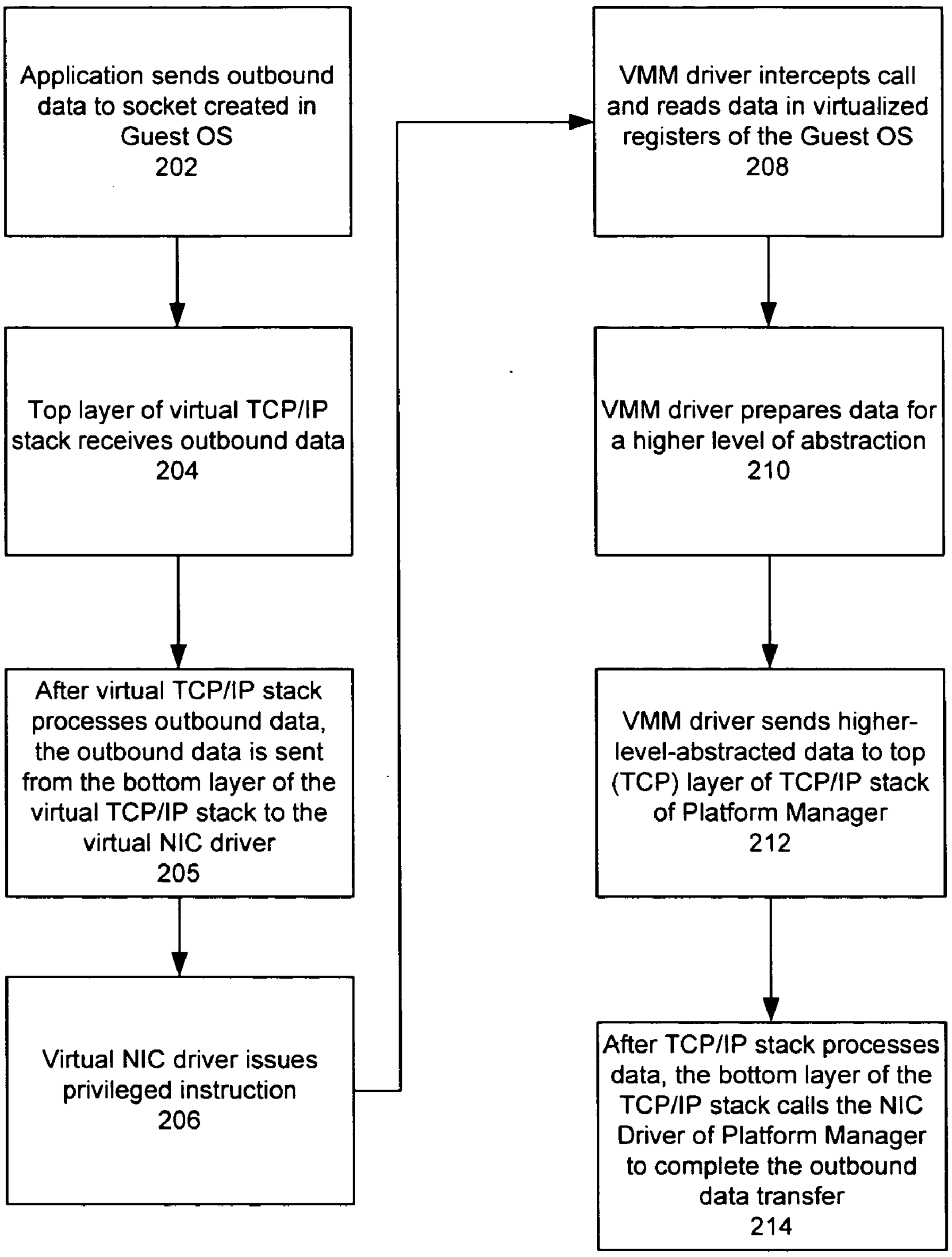

Application sends outbound data to socket created in Guest OS
202
Top layer of virtual TCP/IP stack receives outbound data
204
After virtual TCP/IP stack processes outbound data, the outbound data is sent from the bottom layer of the virtual TCP/IP stack to the virtual NIC driver
205
Virtual NIC driver issues privileged instruction
206
VMM driver intercepts call and reads data in virtualized registers of the Guest OS
208
VMM driver prepares data for a higher level of abstraction
210
VMM driver sends higher-level-abstracted data to top (TCP) layer of TCP/IP stack of Platform Manager
212
After TCP/IP stack processes data, the bottom layer of the TCP/IP stack calls the NIC Driver of Platform Manager to complete the outbound data transfer
214

FIG. 2
(Conventional)

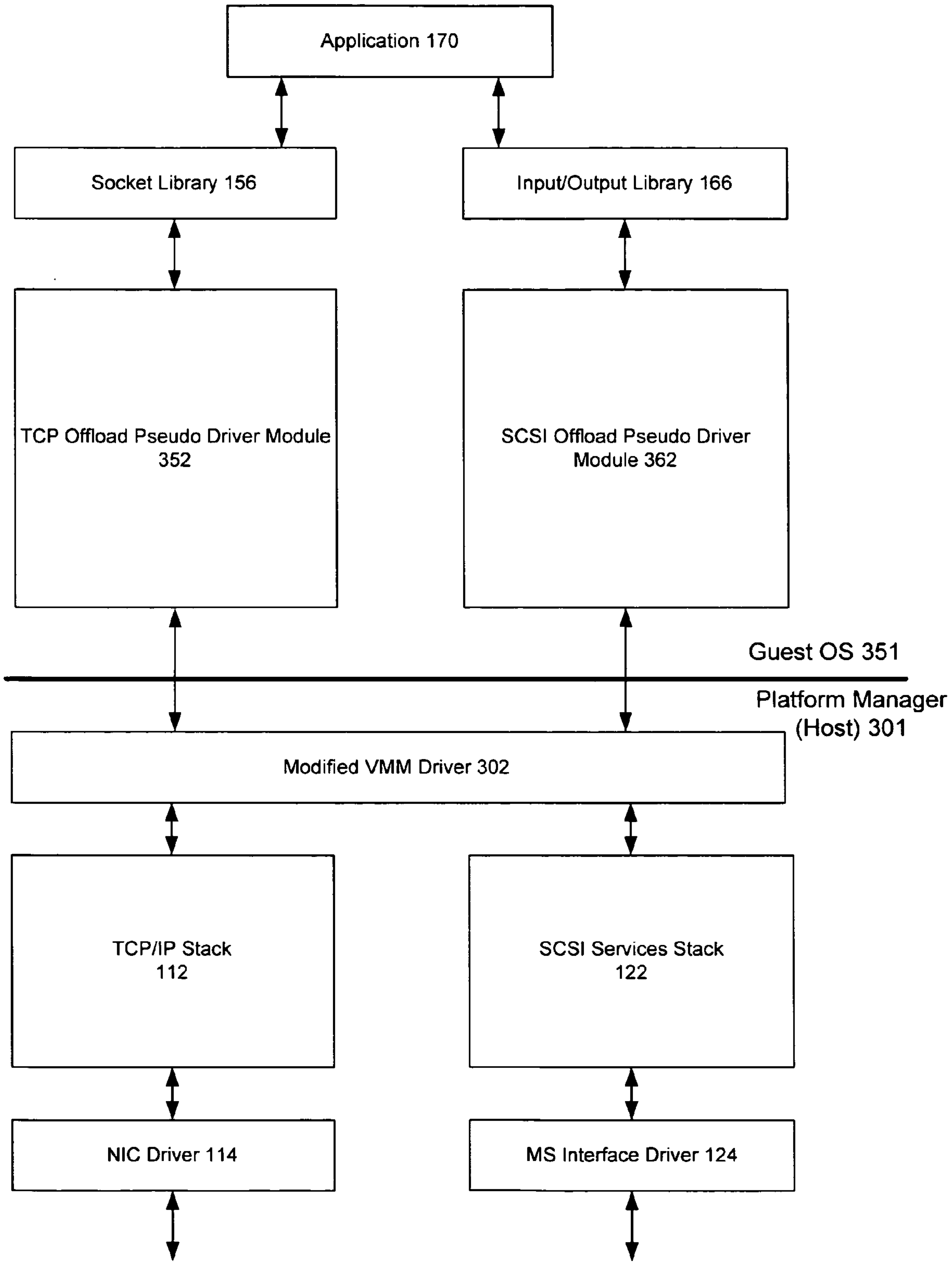

Application 170
Socket Library 156
Input/Output Library 166
TCP Offload Pseudo Driver Module 352
SCSI Offload Pseudo Driver Module 362
Guest OS 351
Platform Manager (Host) 301
Modified VMM Driver 302
TCP/IP Stack 112
SCSI Services Stack 122
NIC Driver 114
MS Interface Driver 124

FIG. 3A

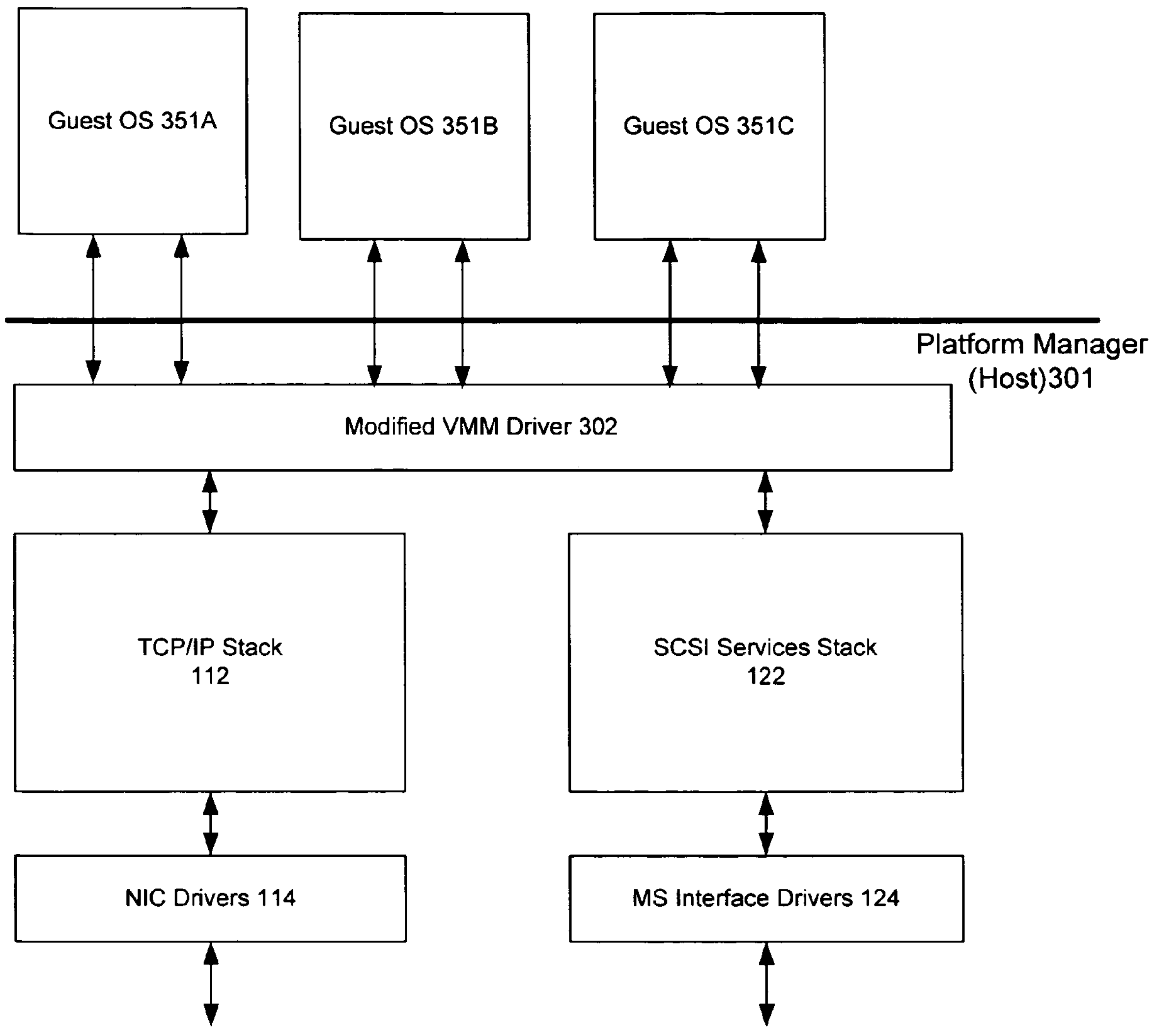

Guest OS 351A
Guest OS 351B
Guest OS 351C
Platform Manager (Host)301
Modified VMM Driver 302
TCP/IP Stack 112
SCSI Services Stack 122
NIC Drivers 114
MS Interface Drivers 124

FIG. 3B

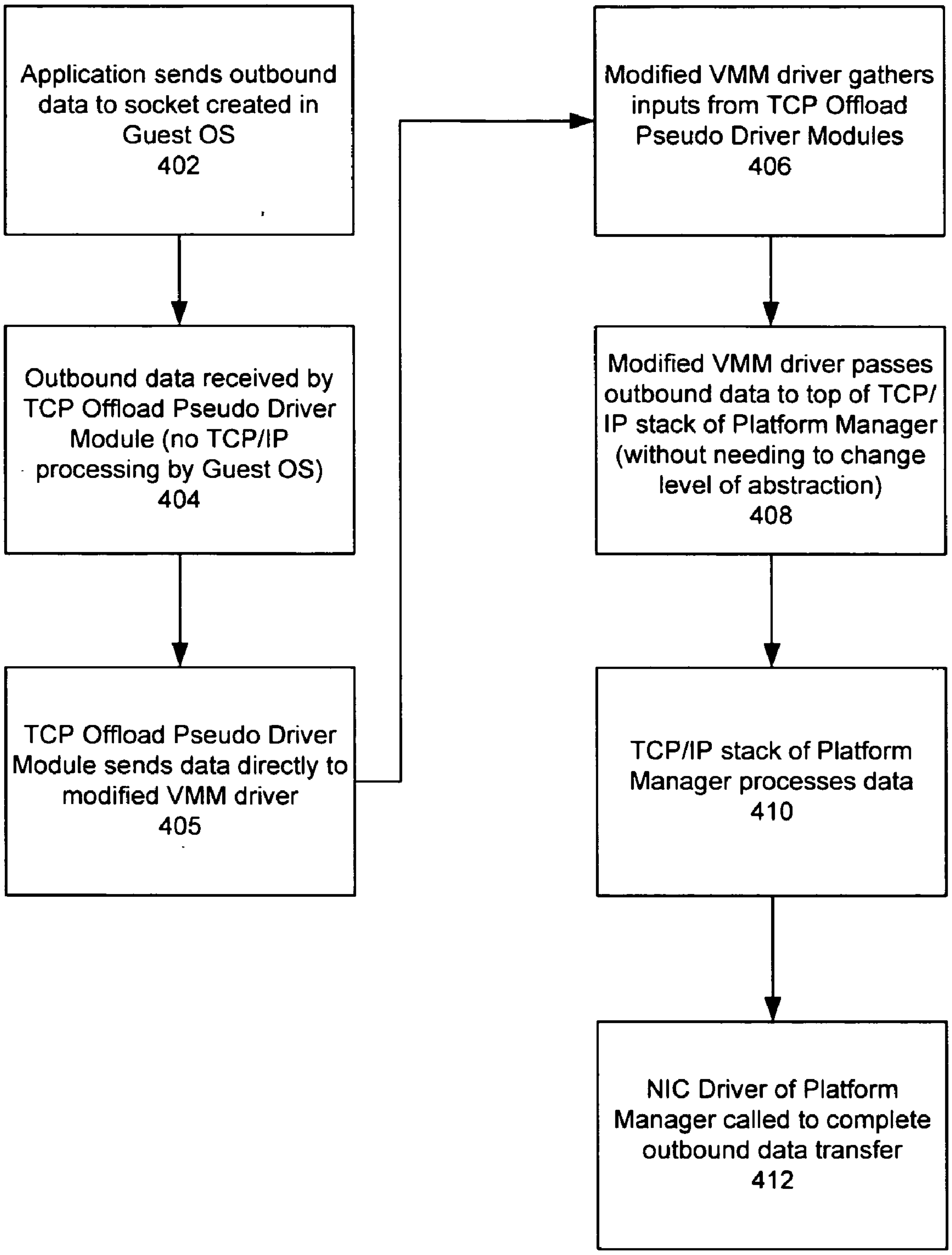

Application sends outbound data to socket created in Guest OS
402
Outbound data received by TCP Offload Pseudo Driver Module (no TCP/IP processing by Guest OS)
404
TCP Offload Pseudo Driver Module sends data directly to modified VMM driver
405
Modified VMM driver gathers inputs from TCP Offload Pseudo Driver Modules
406
Modified VMM driver passes outbound data to top of TCP/IP stack of Platform Manager (without needing to change level of abstraction)
408
TCP/IP stack of Platform Manager processes data
410
NIC Driver of Platform Manager called to complete outbound data transfer
412

FIG. 4

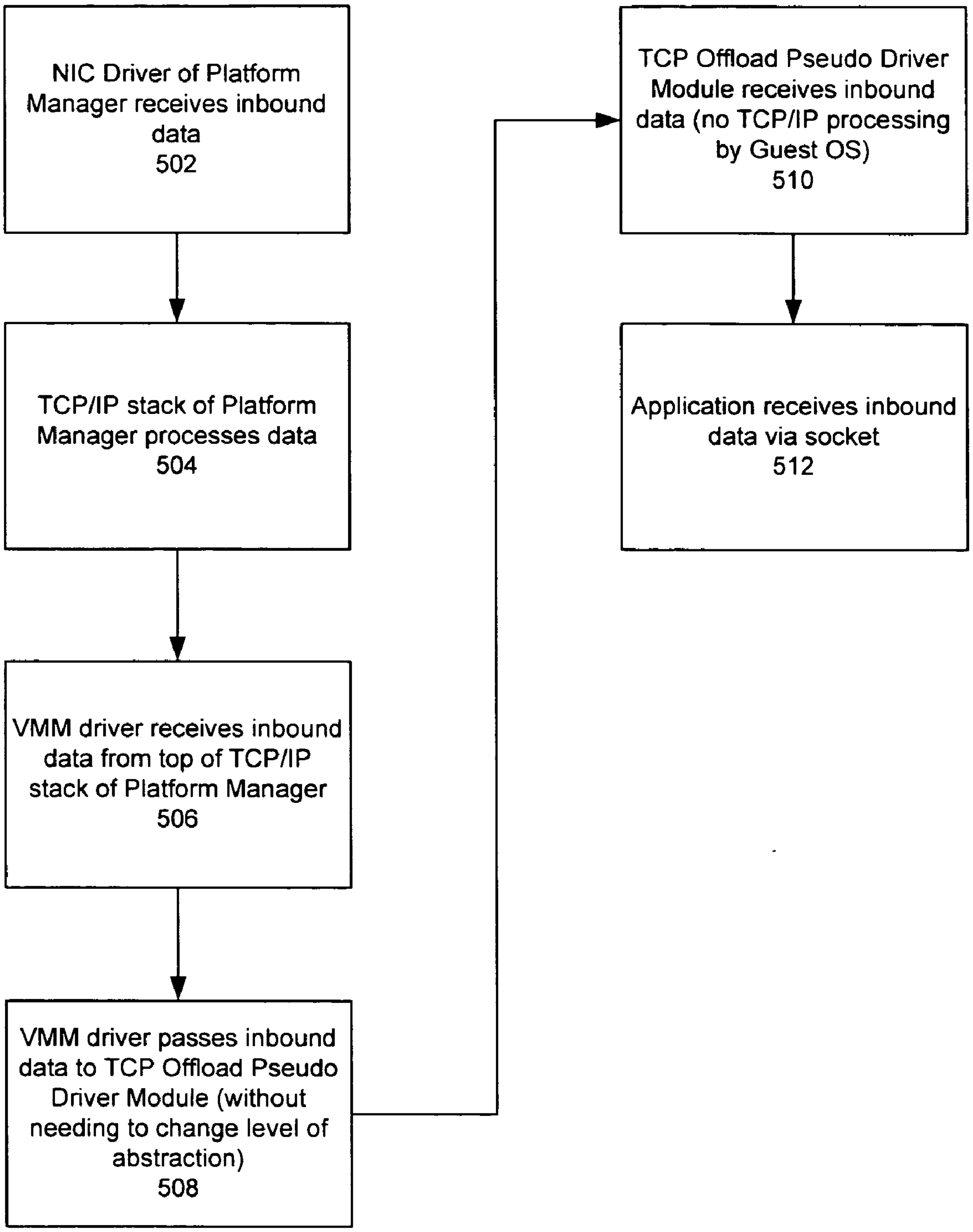

NIC Driver of Platform Manager receives inbound data
502
TCP/IP stack of Platform Manager processes data
504
VMM driver receives inbound data from top of TCP/IP stack of Platform Manager
506
VMM driver passes inbound data to TCP Offload Pseudo Driver Module (without needing to change level of abstraction)
508
TCP Offload Pseudo Driver Module receives inbound data (no TCP/IP processing by Guest OS)
510
Application receives inbound data via socket
512

FIG. 5

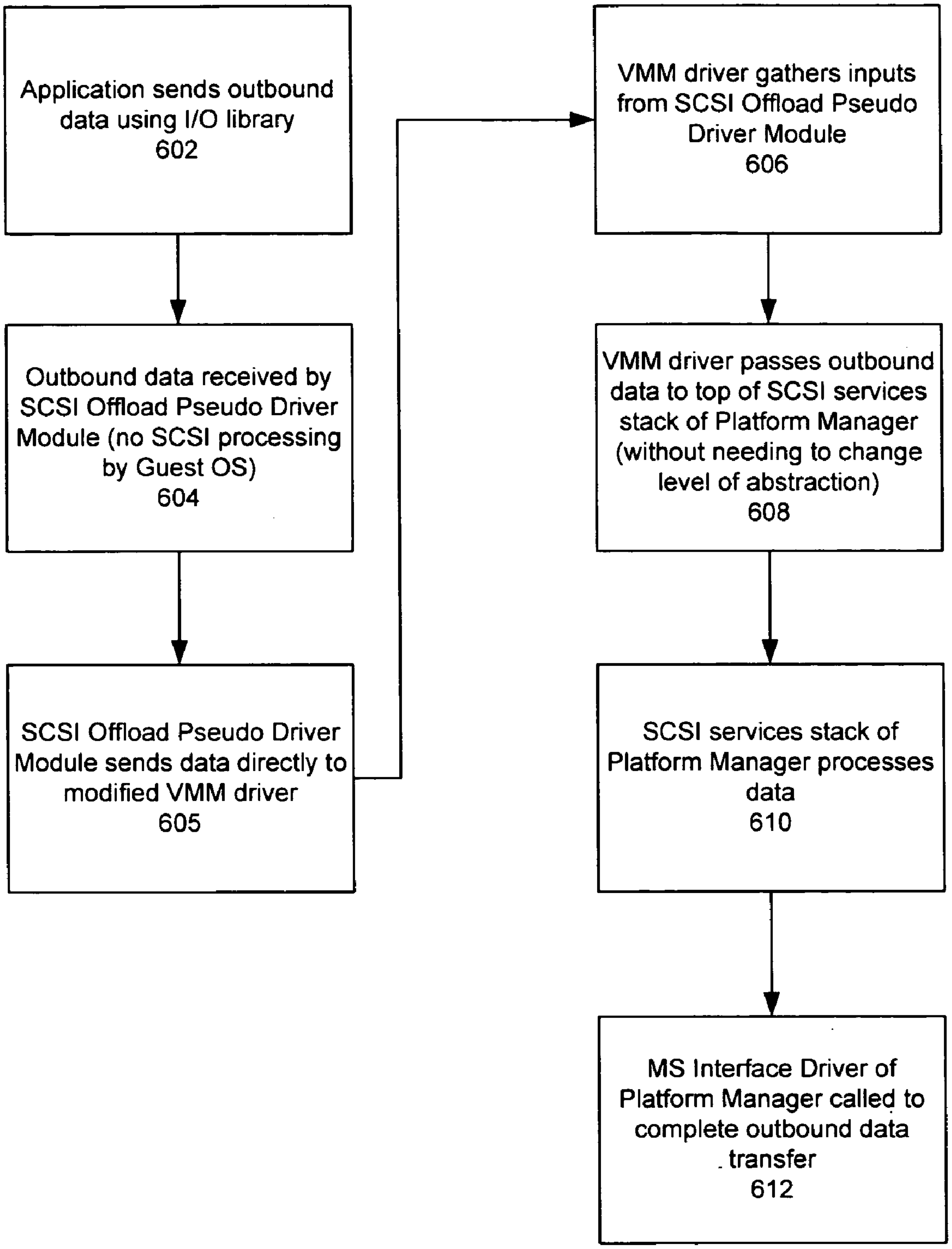

Application sends outbound data using I/O library
602
Outbound data received by SCSI Offload Pseudo Driver Module (no SCSI processing by Guest OS)
604
SCSI Offload Pseudo Driver Module sends data directly to modified VMM driver
605
VMM driver gathers inputs from SCSI Offload Pseudo Driver Module
606
VMM driver passes outbound data to top of SCSI services stack of Platform Manager (without needing to change level of abstraction)
608
SCSI services stack of Platform Manager processes data
610
MS Interface Driver of Platform Manager called to complete outbound data transfer
612

FIG. 6

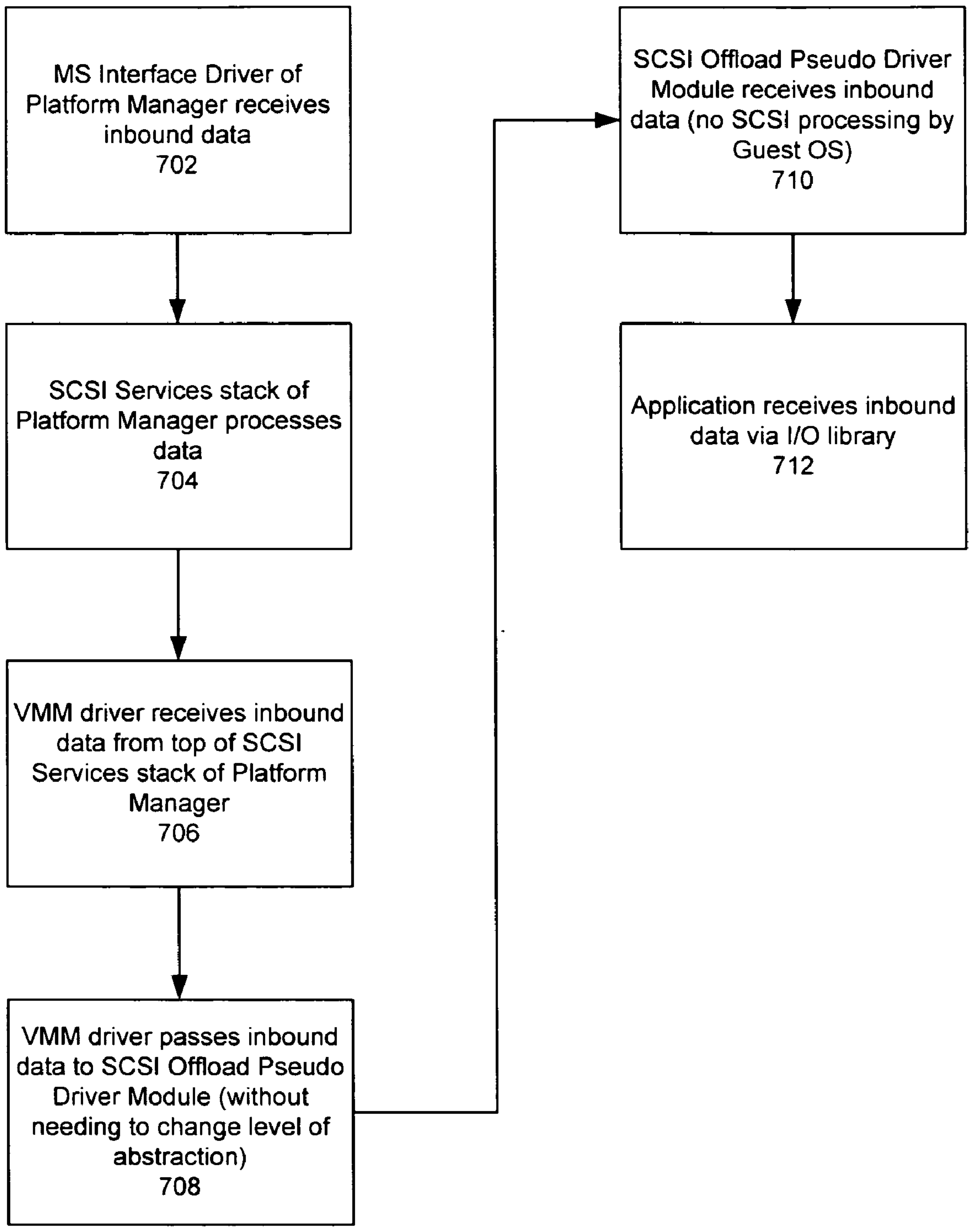

MS Interface Driver of Platform Manager receives inbound data
702
SCSI Services stack of Platform Manager processes data
704
VMM driver receives inbound data from top of SCSI Services stack of Platform Manager
706
VMM driver passes inbound data to SCSI Offload Pseudo Driver Module (without needing to change level of abstraction)
708
SCSI Offload Pseudo Driver Module receives inbound data (no SCSI processing by Guest OS)
710
Application receives inbound data via I/O library
712

FIG. 7

of the virtual SCSI Services stack **164** interfaces with the input/output library **166**. The application **170** communicates input/output data using functions of the socket library **156** and the input/output library **166**.

[0022] The conventional architecture discussed above in relation to FIG. **1** is configured to provide input/output support for multiple virtual computing machines running on a single physical system. An example of a method of operation using the conventional architecture is discussed below in relation to FIG. **2**. While this conventional architecture and method of operation works, applicant has identified a problematic inefficiency in the method. In particular, the I/O data is twice processed by a TCP/IP stack, a first time by the virtual TCP/IP stack of the Guest OS and a second time by the TCP/IP stack of the Kernel.

[0023] FIG. **2** is a flow chart of a process of sending outbound data from an application **170** using the conventional architecture of FIG. **1**. The application **170** sends **202** outbound data to a socket (created using socket library **156**) in the Guest OS **151**. The outbound data is received **204** at the top (TCP) layer of the virtual TCP/IP stack **154**. After processing of the data by the virtual TCP/IP stack **154**, the outbound data is sent **205** from the bottom (IP) layer of the virtual TCP/IP stack **154** to the virtual NIC driver **152**. The virtual NIC driver then issues **206** a call to send the outbound data to a network. The call is privileged in that it relates to accessing a physical resource which is controlled by the Platform Manager **101**.

[0024] The VMM driver **102** intercepts **208** the call and reads data in virtualized registers of the Guest OS **151**. The VMM driver **102** then prepares **210** data for a higher level of abstraction (i.e. for a TCP layer) and sends **212** the higher-level-abstracted data to the top (TCP) layer of the TCP/IP stack **112** of the Platform Manager **101**. After the TCP/IP stack **112** processes the data, the bottom (IP) layer of the TCP/IP stack calls **214** the NIC Driver **114** of Platform Manager **101** to complete the outbound data transfer.

[0025] Problematic issues with the above traditional architecture may be summarized as follows:

[0026] 1. The Guest OS assumes that the virtualized hardware card (for example, a virtual Network Interface Card, also known as a vNIC, and a virtual SCSI card, also known as a vSCSI) is a real card and the appropriate driver processes the data from upper layers (the TCP stack for vNIC and the SCSI Stack for vSCSI). However, the virtualized hardware card could have the same hardware programming interface as the real cards, or could have a different programming interface as the real cards; for example, the real NIC could be based on Intel chip while the vNIC could be having a Broadcom chip programming interface. Therefore, at the point of doing DMA transfer of the data in the queue, the VMM driver intercepts this call, and then interprets the registers of the vNIC memory locations, accesses the data buffer from the Guest OS and re-maps the buffer addresses to a physical address in the VMM address space, does other verifications such as availability and entitlement, etc., and then changes the control data for it to be processed once again by the upper layers (TCP and SCSI stacks). This results in duplicate processing, numerous context switches and additional instructions to modify control data from lower layers to higher layers. The processing overhead in most cases is significant enough to impact I/O performance very detrimentally.

[0027] 2. When I/O bound applications run on Guest OSes, due to the above complexities, the architecture does not scale well, and hence has limited applicability for select workloads in its current form.

[0028] 3. Due to the complexities in context switching among different address spaces, the implementation in the above architecture is quite complex. When additional concepts such as port aggregation and virtual LANs, in case of networking technologies, and multi-pathing and device addressing in case of storage technologies, are added to the mix, the complexity of implementation and usage in this conventional architecture could lead to numerous deployment issues in complex use cases.

[0029] New Architecture

[0030] FIG. 3A is a schematic diagram depicting a virtual machine architecture in accordance with an embodiment of the invention. The diagram shows select software-implemented components and divides them into those of the Platform Manager (Host Kernel) **301** and those of a guest operating system (Guest OS) **351**. These various components may include processor-readable code which is executable to perform various operations and functions.

[0031] Although one Guest OS **351** is shown, multiple Guest OS **351** are supportable by the Platform Manager **301** of the virtual machine architecture. Each Guest OS **351** corresponds to a virtual computing machine or virtual processor running in the system. For example, FIG. 3B shows three guest operating systems (Guest OS **351**A, Guest OS **351**B, and Guest OS **351**C) supported by the Platform Manager **301** of the virtual machine architecture.

[0032] Components in the Platform Manager **301** include a modified VMM driver **302**, a TCP/IP stack **112**, a network interface card (NIC) driver **114**, a SCSI Services stack **122**, and MS Interface drivers **124**. The VMM driver **102** interfaces with the Guest OS **351** of each virtual computing machine running in the system. The modified VMM driver **302** provides kernel-level virtual-machine-related services and implements a context switching mechanism between the host and guest contexts. The TCP/IP stack **112** includes an internet protocol (IP) layer and a transmission control protocol (TCP) layer. The modified VMM driver **302** interfaces with the top of the TCP/IP stack **112** (i.e. with the TCP layer) and the top of the SCSI Services stack **122**. The bottom of the TCP/IP stack **112** (i.e. the IP layer) interfaces with the NIC driver **114**, and the NIC driver **114** interfaces with a network (not shown). The SCSI Services stack **122** interfaces with the MS interface drivers **124**, and the MS interface drivers **124** interface with a storage system (not shown).

[0033] Components of the Guest OS **351** include a TCP Offload Pseudo Driver Module **352**, a socket library **156**, a SCSI Offload Pseudo Driver Module **362**, an input/output library **166**, and one or more applications **170**. An application **170** communicates input/output data using functions of the socket library **156** and the input/output library **166**. The TCP Offload Pseudo Driver Module **352** interfaces with the socket library **156**, and the SCSI Offload Pseudo Driver Module **362** interfaces with the input/output library **166**. Advantageously, no virtual NIC driver **152** and no virtual MS interface drivers **162** are necessarily required. Furthermore, no virtual TCP/IP stack **154** and no virtual SCSI Services stack **164** are necessarily required.

[0034] FIG. **4** is a flow chart of a process of sending outbound networking data using the architecture of FIGS. **3**A and 3B in accordance with an embodiment of the invention. The application **170** sends **402** outbound data to a socket (created using socket library **156**) in the Guest OS **351**. The outbound data is received **404** by the TCP Offload Pseudo Driver Module **352**.

[0035] The TCP Offload Pseudo Driver Module **352** sends **405** the data directly to the modified VMM driver **302** without going through a virtual NIC driver **152**. Advantageously, no TCP/IP processing is performed by the Guest OS **351**. In one implementation, the TCP Offload Pseudo Driver Module **352** may advantageously use a same interface as used for a hardware TCP Offload Engine. Such a hardware TCP Offload Engine utilizes a controller which is separate from the main host microprocessor to improve TCP/IP performance.

[0036] The modified VMM driver **302** gathers **406** inputs (i.e. requests for outbound data transfer) from the TCP Offload Pseudo Driver Modules **352** of the various guest operating systems **351**. These requests for outbound data transfer via the TCP/IP protocol are thus automatically consolidated by the modified VMM driver **302**.

[0037] The modified VMM driver **302** passes **408** the outbound data to the top of the TCP/IP stack **112** of the Platform Manager **301**. Advantageously, there is no need to change the level of abstraction of the data. After the TCP/IP stack **112** processes **410** the data, the NIC Driver **114** of the Platform Manager **301** is called **412** to complete the outbound data transfer.

[0038] FIG. **5** is a flow chart of a process of receiving inbound networking data using the architecture of FIGS. **3**A and **3**B in accordance with an embodiment of the invention. The NIC Driver **114** of the Platform Manager **301** receives **502** an inbound data transfer. The inbound data transfer may be destined for an application in any one of the various Guest OS **351** running on top of the Platform Manager **301**.

[0039] The TCP/IP stack **112** of the Platform Manager **301** processes **504** the data, and the modified VMM driver **302** receives **506** the inbound data to the top of the TCP/IP stack **112** of the Platform Manager **301**. The modified VMM driver **302** passes **508** the inbound data directly to the TCP Offload Pseudo Driver Module **352** without going through a virtual NIC driver **152**. Advantageously, there is no need for the modified VMM driver **302** to change the level of abstraction of the data. In contrast, such a change in the level of abstraction is necessary in the conventional architecture shown in FIG. **1**.

[0040] The TCP Offload Pseudo Driver Module **352** receives **510** the inbound data. Advantageously, no TCP/IP processing is performed by the TCP Offload Pseudo Driver Module **352**. In contrast, such TCP/IP processing is performed by the virtual TCP/IP stack in the conventional architecture shown in FIG. **1**. Finally, the application **170** receives **512** the inbound data via a socket (created using socket library **156**) in the Guest OS **351**.

[0041] FIG. **6** is a flow chart of a process of sending outbound data to a data storage system using the architecture of FIGS. **3**A and **3**B in accordance with an embodiment of the invention. The application **170** sends **602** the outbound data to the data storage system using the I/O library **166**. Consider, for example, that the data storage system is a direct attach SCSI storage system. In other embodiments of the invention, other data storage systems may be used, such as using Fiber Channel or various other technologies. In the case of a SCSI system, the outbound data is received **604** by the SCSI Offload Pseudo Driver Module **362**.

[0042] The SCSI Offload Pseudo Driver Module **362** sends **605** the data directly to the modified VMM driver **302** without going through a virtual MS Interface driver **162**. Advantageously, no SCSI processing is performed by the Guest OS **351**.

[0043] The modified VMM driver **302** gathers **606** inputs (i.e. requests for outbound data transfer) from the SCSI Offload Pseudo Driver Modules **362** of the various guest operating systems **351**. These requests for outbound data transfer to the storage system are thus automatically consolidated by the modified VMM driver **302**.

[0044] The modified VMM driver **302** passes **608** the outbound data to the top of the SCSI Services stack **122** of the Platform Manager **301**. Advantageously, there is no need to change the level of abstraction of the data. After the SCSI Services stack **122** processes **610** the data, the MS Interface Drivers **124** of the Platform Manager **301** is called **612** to complete the outbound data transfer.

[0045] FIG. **7** is a flow chart of a process of receiving inbound data from a data storage system using the architecture of FIGS. **3**A and **3**B in accordance with an embodiment of the invention. The MS Interface Driver **124** of the Platform Manager **301** receives **702** an inbound data transfer. The inbound data transfer may be destined for an application in any one of the various Guest OS **351** running on top of the Platform Manager **301**.

[0046] The SCSI Services stack **122** of the Platform Manager **301** processes **704** the data, and the modified VMM driver **302** receives **706** the inbound data to the top of the SCSI Services stack **122** of the Platform Manager **301**. The modified VMM driver **302** passes **708** the inbound data directly to the SCSI Offload Pseudo Driver Module **362** without going through a virtual MS Interface driver **162**. Advantageously, there is no need for the modified VMM driver **302** to change the level of abstraction of the data. In contrast, such a change in the level of abstraction is necessary in the conventional architecture shown in FIG. **1**.

[0047] The SCSI Offload Pseudo Driver Module **362** receives **710** the inbound data. Advantageously, no SCSI processing is performed by the SCSI Offload Pseudo Driver Module **362**. In contrast, such SCSI processing is performed by the virtual SCSI Services stack in the conventional architecture shown in FIG. **1**. Finally, the application **170** receives **712** the inbound data via the I/O library **166** in the Guest OS **351**.

CONCLUSION

[0048] Applicant has discovered bottlenecks and inefficiencies in input/output transactions in at least some conventional virtual machine architectures. A conventional architecture has the guest OS process input/output at the interface driver level, and when the interface driver in the guest OS tries to issue a privileged instruction (such as initiating a direct memory access), the platform manager operating system intercepts the call. The VMM sub-system (i.e. the VMM driver) in the platform manager then reads the data in the virtualized registers from the guest OS, prepares the data to a higher level of abstraction (DLPI driver level for networking, and SCSI services layer for mass storage) and calls the appropriate driver in the platform manager to complete the input/output (after mapping the virtual I/O to the appropriate device). Similarly, when the platform manager receives any I/O interrupts from a hardware I/O card, the VMM sub-system issues a corresponding interrupt to the guest OS driver which then processes the interrupt as though it occurred from a real I/O device.

[0049] In both the outbound and the inbound paths for a conventional architecture, there are several performance bottlenecks and inefficiencies which add to I/O performance overheads. The bottlenecks and inefficiencies may include context-switching for every low level I/O call from the guest to host (platform manager), copying of the buffers, marshalling low level data into higher level data, dual stack processing (DLPI for networking and SCSI Services for mass storage I/O), and dual interrupt processing (both at host and guest for every low level interrupt from any I/O device meant for a guest). These bottlenecks and inefficiencies may be significant for heavy I/O workloads.

[0050] The present application discloses a solution to the above-discussed bottlenecks and inefficiencies. The solution involves input/output virtualization through offload techniques. The solution advantageously improves input/output performance while simplifying implementation. Furthermore, it is readily scalable to new I/O cards for both mass storage and networking.

[0051] For networking, the guest OS uses a TCP Offload Engine (TOE) interface and assumes a virtual hardware TOE card. In the outbound path, the guest OS offloads the I/O to the platform manager at the top of the TCP/IP stack itself (i.e. no TCP/IP processing in the guest OS). The VMM sub-system then gathers the data inputs from the TOE pseudo driver in the guest OS, and passes the data to the host TCP stack for further processing on the outbound. Similarly, in the inbound path, all NIC-level interrupts are completely consumed by the host (platform manager), and only after the entire TCP packet is received and processes will the host issue a soft-interrupt to the Guest OS for the TOE pseudo driver to receive the TCP packet and pass it on to applications.

[0052] For data storage, a similar SCSI offload pseudo driver in the guest OS may be configured to assume virtual SCSI services offload hardware. In the outbound path, the guest OS offloads the I/O to the platform manager at the top of the SCSI services stack (without doing SCSI services processing in the guest OS). This is done by a call from the SCSI offload pseudo driver to the virtual SCSI services offload hardware. This call is intercepted by the VMM sub-system in the platform manager. The VMM sub-system passes the intercepted data to the SCSI services stack in the host for normal processing. In the inbound path, the host interface drivers and the SCSI services stack do all the low-level processing, and when the data is ready for passing to the upper layers above SCSI services, then the platform manager issues a soft interrupt to the guest operating system, where the interrupt service routine (ISR) of the SCSI offload pseudo driver takes the data and passes it on to the guest applications (without doing SCSI services processing).

[0053] There are several advantages to the solution disclosed herein. First, for both networking and mass storage, since the guest-to-host transition for input/output occurs at a very high level (above TCP/IP and SCSI services stacks). This will generally reduce the number of such transitions because the packet sizes at these higher levels could be and typically are much larger than at lower levels. For outbound data, these larger packets may be broken up into smaller packets by the host OS before the actual input/output, and so there is no per-packet overhead at the lowest levels as in the conventional architecture. Similarly, for inbound data, several hardware level interrupts are completely handled and consumed by the host OS, with the guest OS seeing a single interrupt after higher-level data is ready to be delivered.

[0054] In addition, the native operating system's interfaces for TCP offload and for plugging modules above SCSI services may be re-used to insert the pseudo-drivers. This same mechanism may be used for a variety of NIC cards in the host, as well as for a variety of mass storage host bus adaptors (HBAs) and technologies (for example, fiber channel, SCSI, serial attached SCSI (SAS), and so on).

[0055] Furthermore, newer cards in the host may be automatically supported in the guest operating system with no further modification or qualification because the guest operating system is abstracted from link level technologies due to higher level offloading. Also, as new performance enhancements are introduced into the platform manager operating system, these enhancements may be seen automatically in the various guest operating systems without modifying the guest operating systems. For example, the introduction of a more efficient SCSI services stack in the host would benefit various guests (for example, an HP-UX guest, a Windows guest, and a Linux guest) without further modification of those guest operating systems.

[0056] In the above description, numerous specific details are given to provide a thorough understanding of embodiments of the invention. However, the above description of illustrated embodiments of the invention is not intended to be exhaustive or to limit the invention to the precise forms disclosed. One skilled in the relevant art will recognize that the invention can be practiced without one or more of the specific details, or with other methods, components, etc. In other instances, well-known structures or operations are not shown or described in detail to avoid obscuring aspects of the invention. While specific embodiments of, and examples for, the invention are described herein for illustrative purposes, various equivalent modifications are possible within the scope of the invention, as those skilled in the relevant art will recognize.

[0057] These modifications can be made to the invention in light of the above detailed description. The terms used in the following claims should not be construed to limit the invention to the specific embodiments disclosed in the specification and the claims. Rather, the scope of the invention is to be determined by the following claims, which are to be construed in accordance with established doctrines of claim interpretation.

[0058] Recently, other competitive approaches have been used to solve the problem of I/O inefficiencies. One approach, called Direct I/O, maps the virtual hardware (vNIC and vSCSI) directly to a real hardware (NIC and SCSI/FC) in the VMM module. The VMM driver upon intercepting hardware calls in the Guest OS will map the calls directly to the Platform Manager's drivers controlling real hardware and bypasses the upper layer stacks in the Platform Manager (such as the TCP stack and SCSI stack). While on the I/O front, this approach has the same advantage as the implementation disclosed in this patent application, the biggest disadvantage to Direct I/O approach is that the real hardware can no longer be virtualized among many different Guest OSes. In other words, each Guest OS will now need to have its own real hardware, which removes all virtualization of I/O for such hardware resources. The architecture described in the present disclosure eliminates the I/O issues in the conventional architecture while still retaining virtualization of I/O resources, unlike the alternate approach pursued in Direct I/O.

What is claimed is:

1. A computer apparatus providing support for multiple virtual computing machines, the apparatus comprising:

a platform manager configured to support multiple guest operating systems;

a virtual machine manager (VMM) driver of the platform manager;

a TCP/IP (transmission control protocol/internet protocol) stack of the platform manager;

a guest operating system supported by the platform manager; and

a TCP (transmission control protocol) offload pseudo driver module of the guest operating system,

wherein the VMM driver is configured to transfer data between a top of the TCP/IP stack and the TCP offload pseudo driver module without changing a level of abstraction of the data.

2. The apparatus of claim **1**, wherein TCP/IP processing is not performed by the TCP offload pseudo driver module of the guest operating system.

3. The apparatus of claim **1**, wherein the data comprises outbound data to a network, and the TCP offload pseudo driver module is configured to receive the outbound data from an application via a socket created in the guest operating system.

4. The apparatus of claim **1**, wherein the data comprises inbound data from a network, and the TCP offload pseudo driver module is configured to send the inbound data to an application via a socket created in the guest operating system.

5. A computer apparatus providing support for multiple virtual computing machines, the apparatus comprising:

a platform manager configured to support multiple guest operating systems;

a virtual machine manager (VMM) driver of the platform manager;

a storage services stack of the platform manager;

a guest operating system supported by the platform manager; and

a storage offload pseudo driver module of the guest operating system,

wherein the VMM driver is configured to transfer data between a top of the storage services stack and the storage offload pseudo driver module without changing a level of abstraction of the data.

6. The apparatus of claim **5**, wherein storage services processing is not performed by the storage offload pseudo driver module of the guest operating system.

7. The apparatus of claim **5**, wherein the data comprises outbound data to a storage system, and the storage offload pseudo driver module is configured to receive the outbound data from an application using an input/output library.

8. The apparatus of claim **1**, wherein the data comprises inbound data from a storage system, and the storage offload pseudo driver module is configured to send the inbound data to an application using an input/output library.

9. The apparatus of claim **5**, wherein the storage services stack comprises a small computer system interface (SCSI) services stack.

10. A method of input/output virtualization, the method comprising transferring data between a top of a TCP/IP stack of a platform manager and a TCP offload pseudo driver module of a guest operating system using a virtual machine manager (VMM) driver without changing a level of abstraction of the data, wherein the platform manager is configured to support multiple guest operating systems.

11. The method of claim **10**, wherein TCP/IP processing is not performed by the TCP offload pseudo driver module of the guest operating system.

12. The method of claim **10**, wherein the data comprises outbound data to a network, further comprising:

creating a socket in the guest operating system; and

receiving the outbound data by the TCP offload pseudo driver module from an application via the socket.

13. The method of claim **10**, wherein the data comprises inbound data from a network, further comprising:

creating a socket in the guest operating system; and

sending the inbound data by the TCP offload pseudo driver module to an application via the socket.

14. A method of input/output virtualization, the method comprising transferring data between a top of a storage services stack of a platform manager and a storage offload pseudo driver module of a guest operating system using a virtual machine manager (VMM) driver without changing a level of abstraction of the data, wherein the platform manager is configured to support multiple guest operating systems.

15. The method of claim **14**, wherein storage services processing is not performed by the storage offload pseudo driver module of the guest operating system.

16. The method of claim **14**, wherein the data comprises outbound data to a storage system, further comprising:

receiving the outbound data by the storage offload pseudo driver module from an application by way of an input/output library.

17. The method of claim **14**, wherein the data comprises inbound data from a storage system, further comprising:

sending the inbound data by the storage offload pseudo driver module to an application by way of an input/output library.

18. The method of claim **14**, wherein the storage services stack comprises a small computer system interface (SCSI) services stack.

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