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(54) TRANSMIT SIDE SCALING AND ALIGNMENT

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(51) **Int. Cl.**

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G06F 9/455	(2018.01)
G06F 13/38	(2006.01)
H04L 47/6295	(2022.01)

(52) **U.S. Cl.**

CPC ***H04L 47/6295*** (2013.01); ***G06F 9/45558*** (2013.01); ***G06F 9/545*** (2013.01); ***G06F 13/38*** (2013.01); *G06F 2009/45595* (2013.01); *G06F 2209/548* (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

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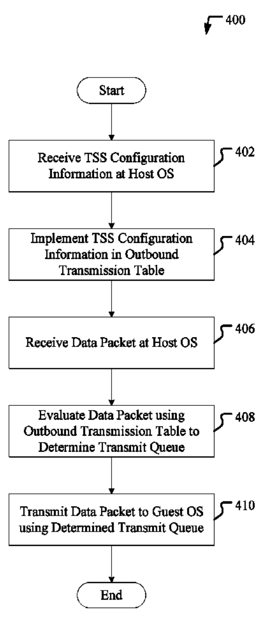
Primary Examiner — Craig C Dorais

(57) **ABSTRACT**

Examples of the present disclosure describe systems and methods for transmit side scaling. In examples, transmission side configuration information is received by a host operating system from a guest operating system, where the transmission side scaling configuration information specifies the manner in which data packets transmitted by the host operating system are to be distributed to a network interface card of the host operating system. The transmission side configuration scaling information is implemented in an outbound transmission table of the host operating system. When a data packet is received by the host operating system, the host operating system evaluates the data packet using the outbound transmission table. Based on the evaluation, that data packet is transmitted using a specified transmit queue of the network interface card.

20 Claims, 10 Drawing Sheets


400
Start
Receive TSS Configuration Information at Host OS
402
Implement TSS Configuration Information in Outbound Transmission Table
404
Receive Data Packet at Host OS
406
Evaluate Data Packet using Outbound Transmission Table to Determine Transmit Queue
408
Transmit Data Packet to Guest OS using Determined Transmit Queue
410
End

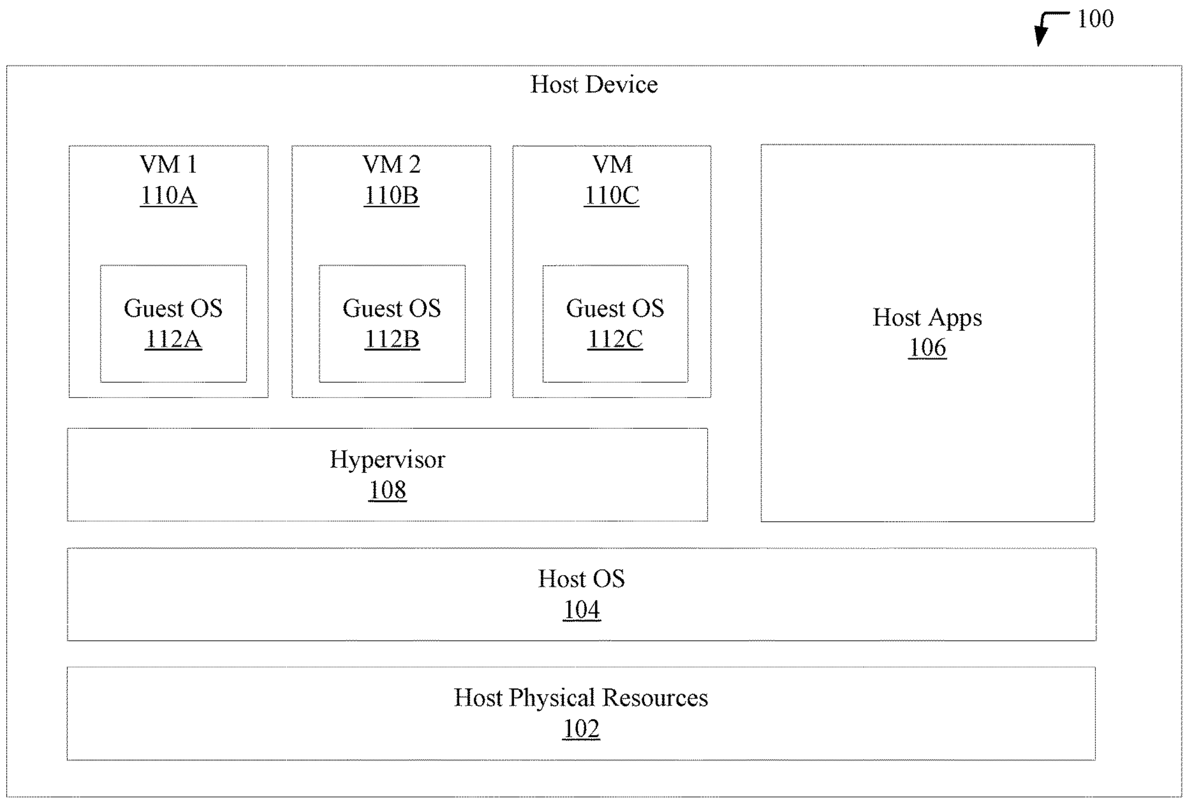

100
Host Device
VM 1
110A
VM 2
110B
VM
110C
Guest OS
112A
Guest OS
112B
Guest OS
112C
Host Apps
106
Hypervisor
108
Host OS
104
Host Physical Resources
102

FIG. 1

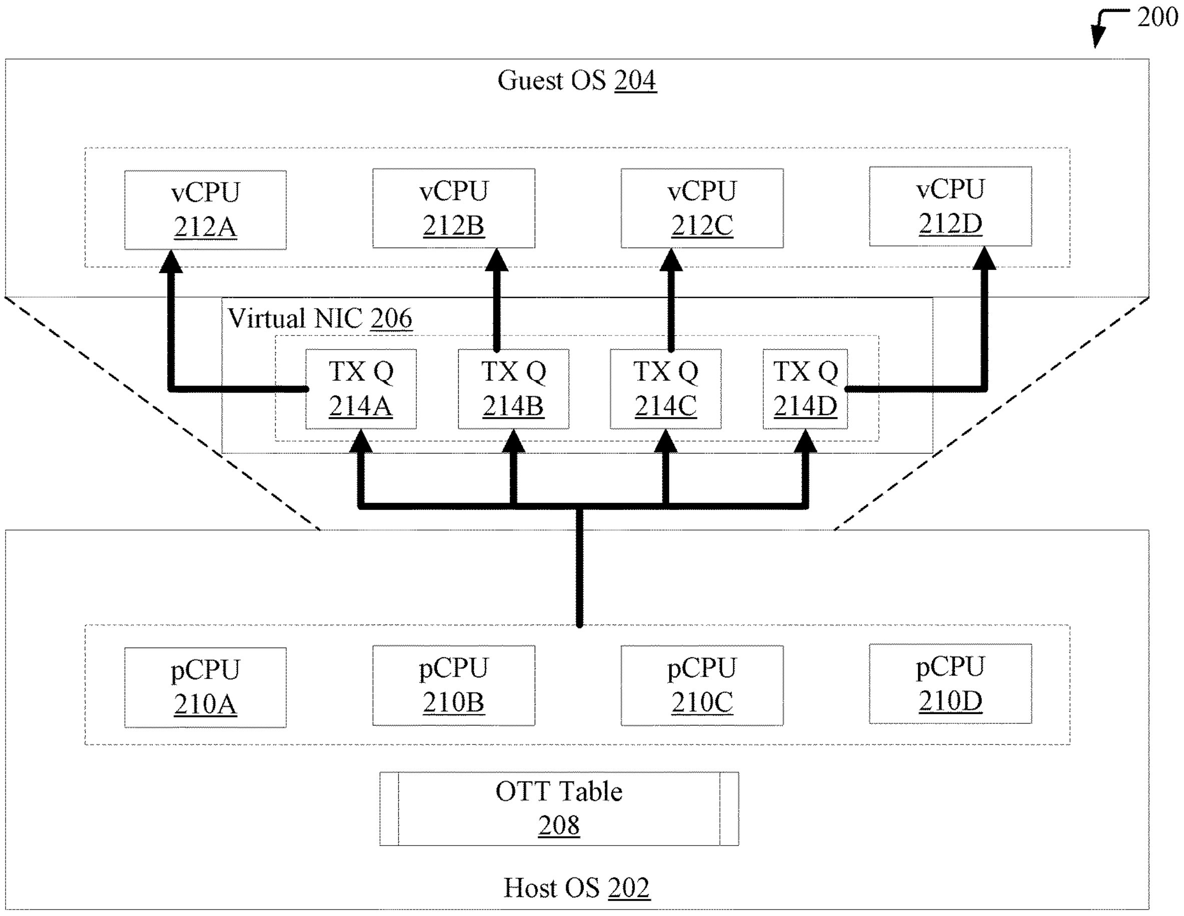

200
Guest OS 204
vCPU 212A
vCPU 212B
vCPU 212C
vCPU 212D
Virtual NIC 206
TX Q 214A
TX Q 214B
TX Q 214C
TX Q 214D
pCPU 210A
pCPU 210B
pCPU 210C
pCPU 210D
OTT Table 208
Host OS 202

FIG. 2A

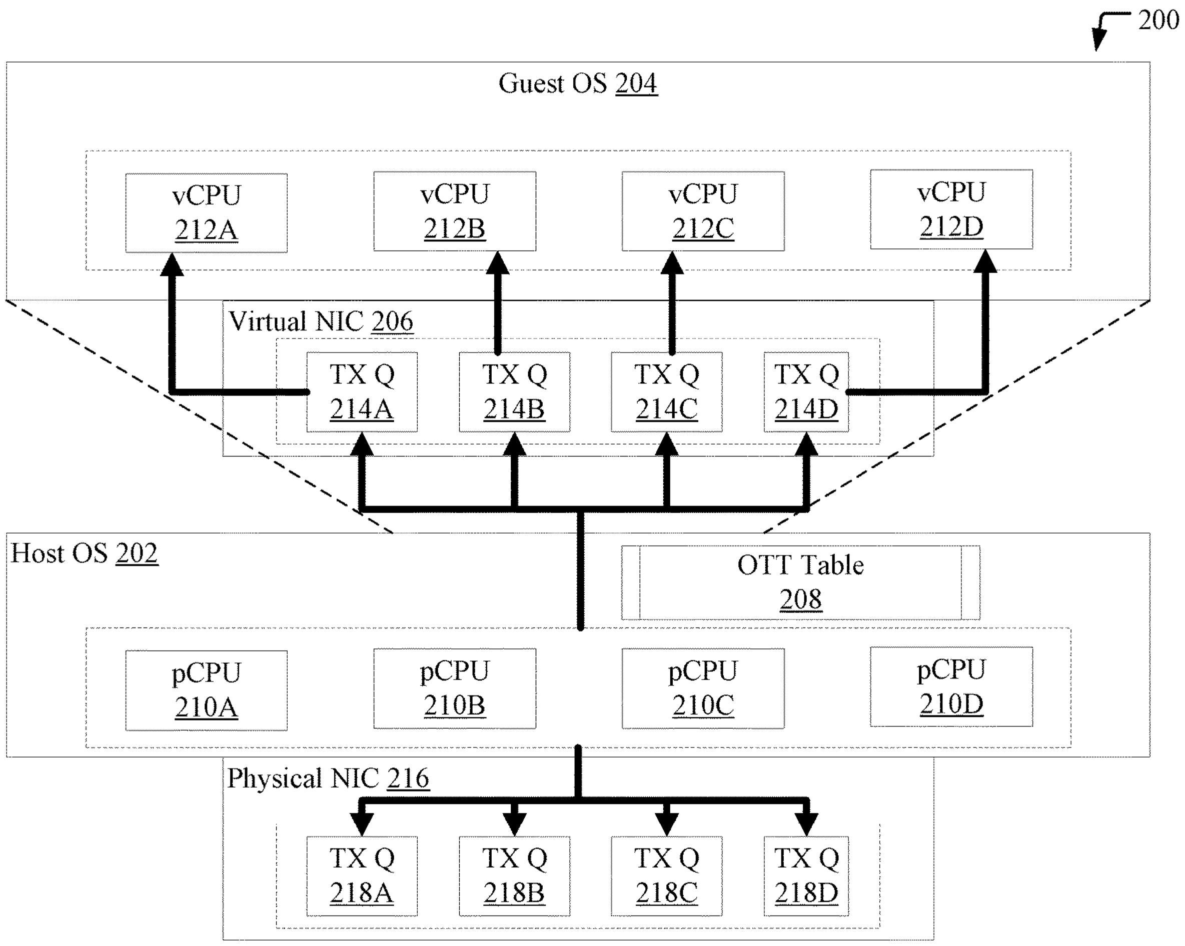

200
Guest OS 204
vCPU 212A
vCPU 212B
vCPU 212C
vCPU 212D
Virtual NIC 206
TX Q 214A
TX Q 214B
TX Q 214C
TX Q 214D
Host OS 202
OTT Table 208
pCPU 210A
pCPU 210B
pCPU 210C
pCPU 210D
Physical NIC 216
TX Q 218A
TX Q 218B
TX Q 218C
TX Q 218D

FIG. 2B

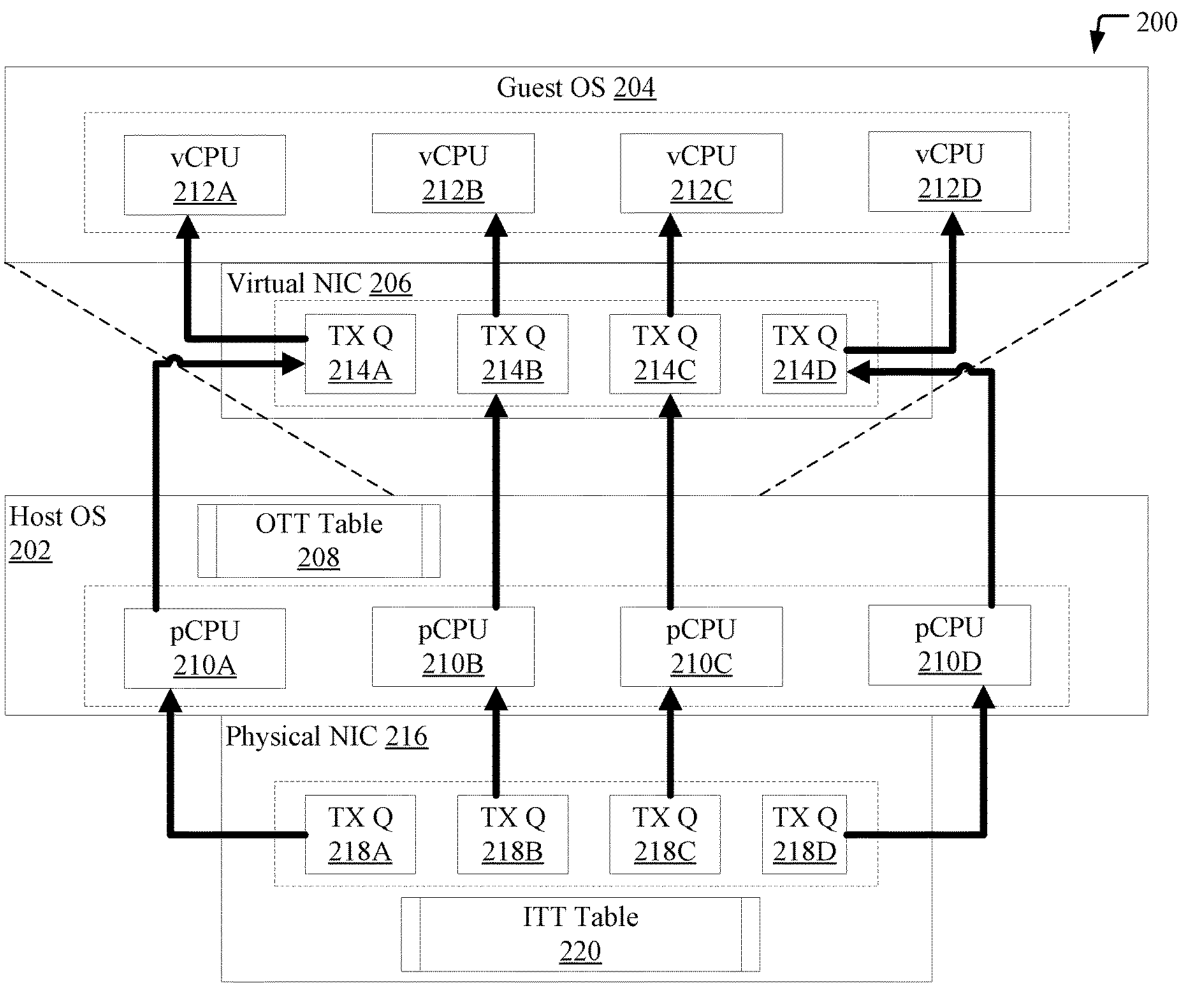

200
Guest OS 204
vCPU 212A
vCPU 212B
vCPU 212C
vCPU 212D
Virtual NIC 206
TX Q 214A
TX Q 214B
TX Q 214C
TX Q 214D
Host OS 202
OTT Table 208
pCPU 210A
pCPU 210B
pCPU 210C
pCPU 210D
Physical NIC 216
TX Q 218A
TX Q 218B
TX Q 218C
TX Q 218D
ITT Table 220

FIG. 3

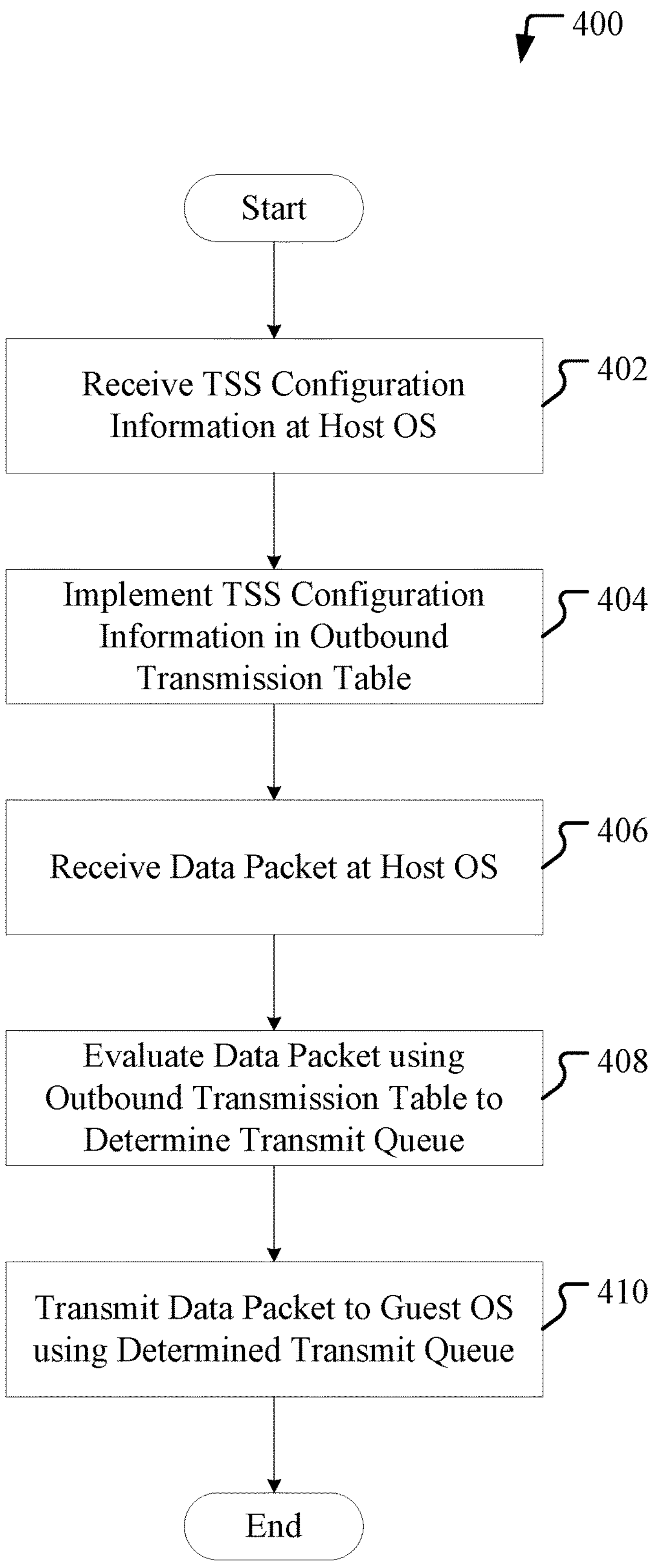

400
Start
Receive TSS Configuration Information at Host OS
402
Implement TSS Configuration Information in Outbound Transmission Table
404
Receive Data Packet at Host OS
406
Evaluate Data Packet using Outbound Transmission Table to Determine Transmit Queue
408
Transmit Data Packet to Guest OS using Determined Transmit Queue
410
End

FIG. 4

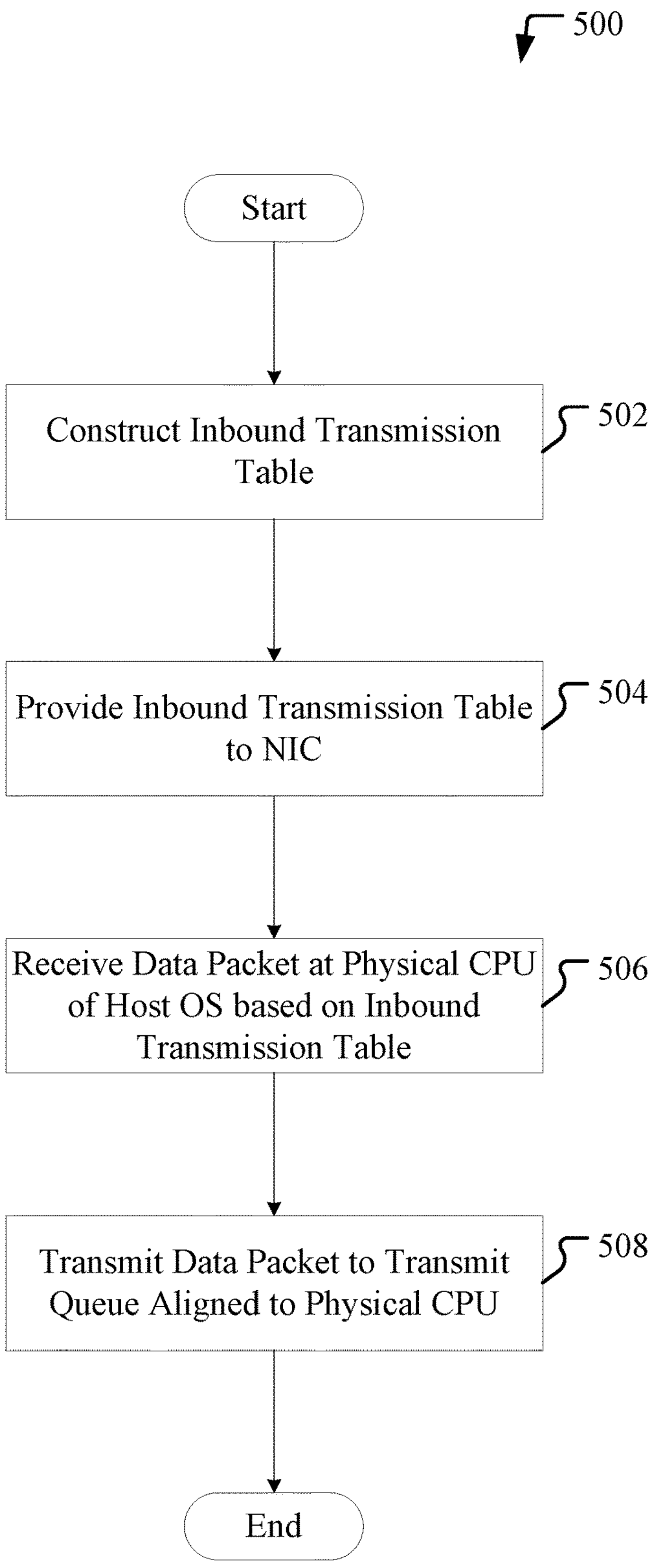

500
Start
Construct Inbound Transmission Table
502
Provide Inbound Transmission Table to NIC
504
Receive Data Packet at Physical CPU of Host OS based on Inbound Transmission Table
506
Transmit Data Packet to Transmit Queue Aligned to Physical CPU
508
End

FIG. 5

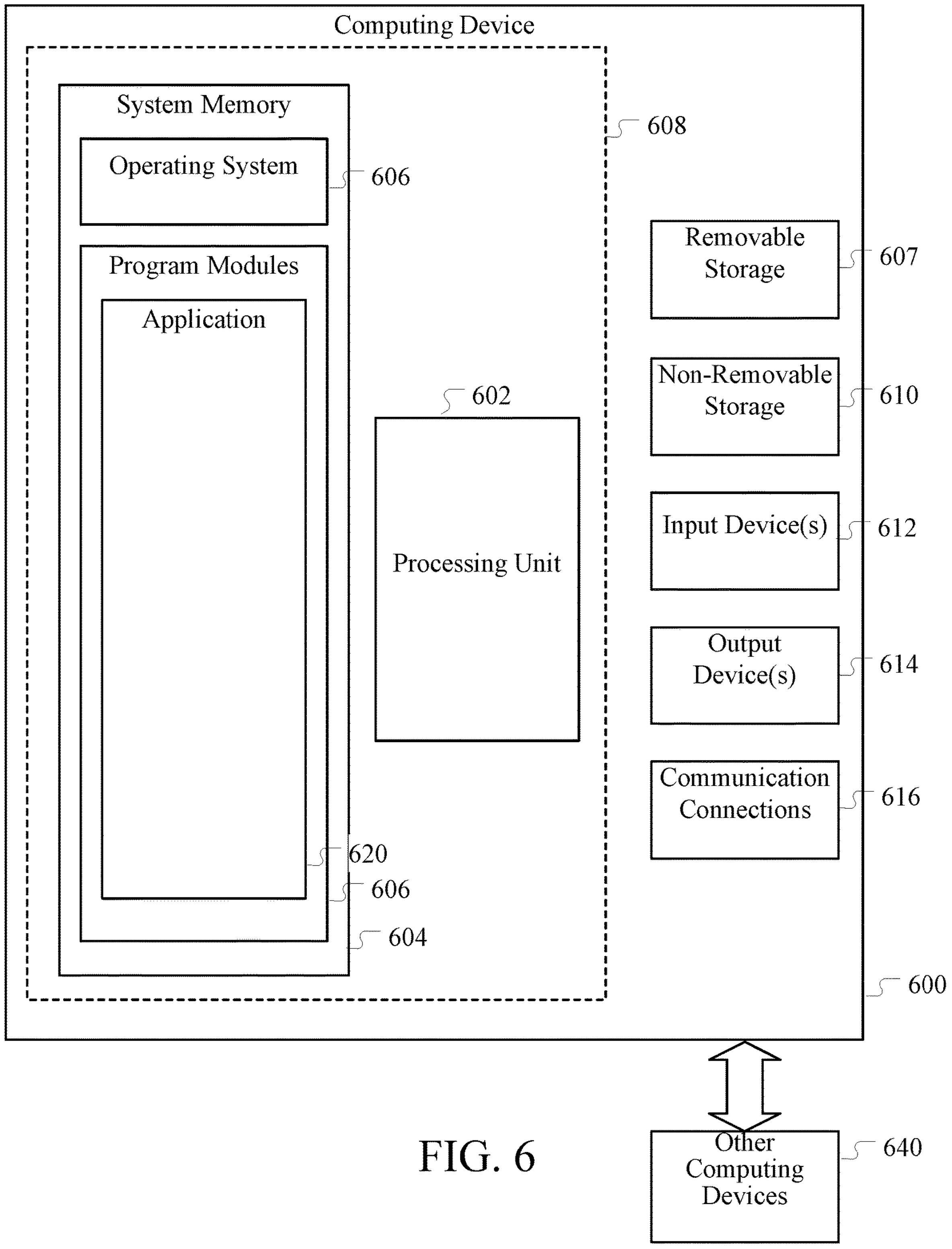

Computing Device
System Memory
Operating System
Program Modules
Application
Processing Unit
Removable Storage
Non-Removable Storage
Input Device(s)
Output Device(s)
Communication Connections
Other Computing Devices
600
602
604
606
606
607
608
610
612
614
616
620
640

FIG. 6

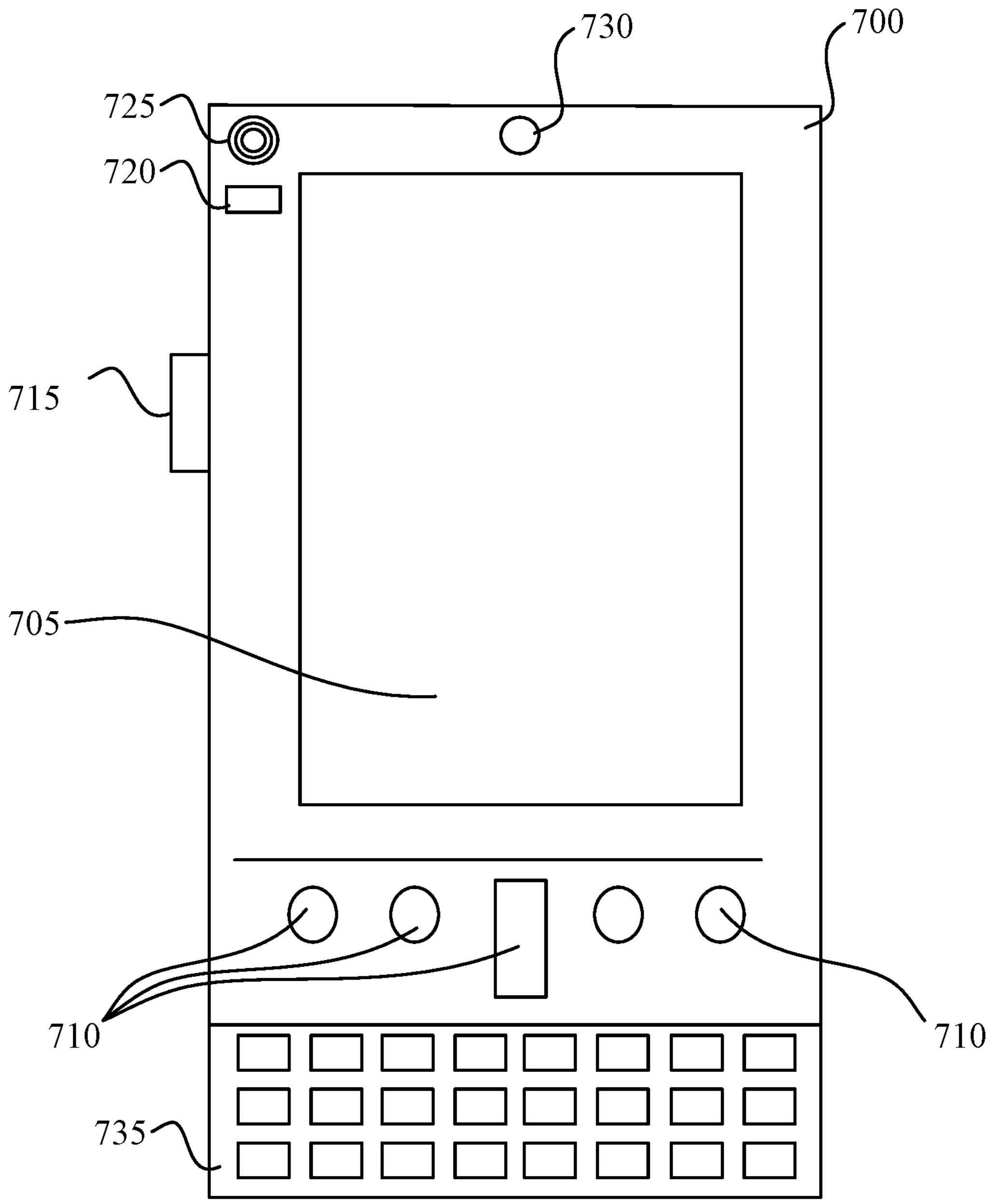


FIG. 7A

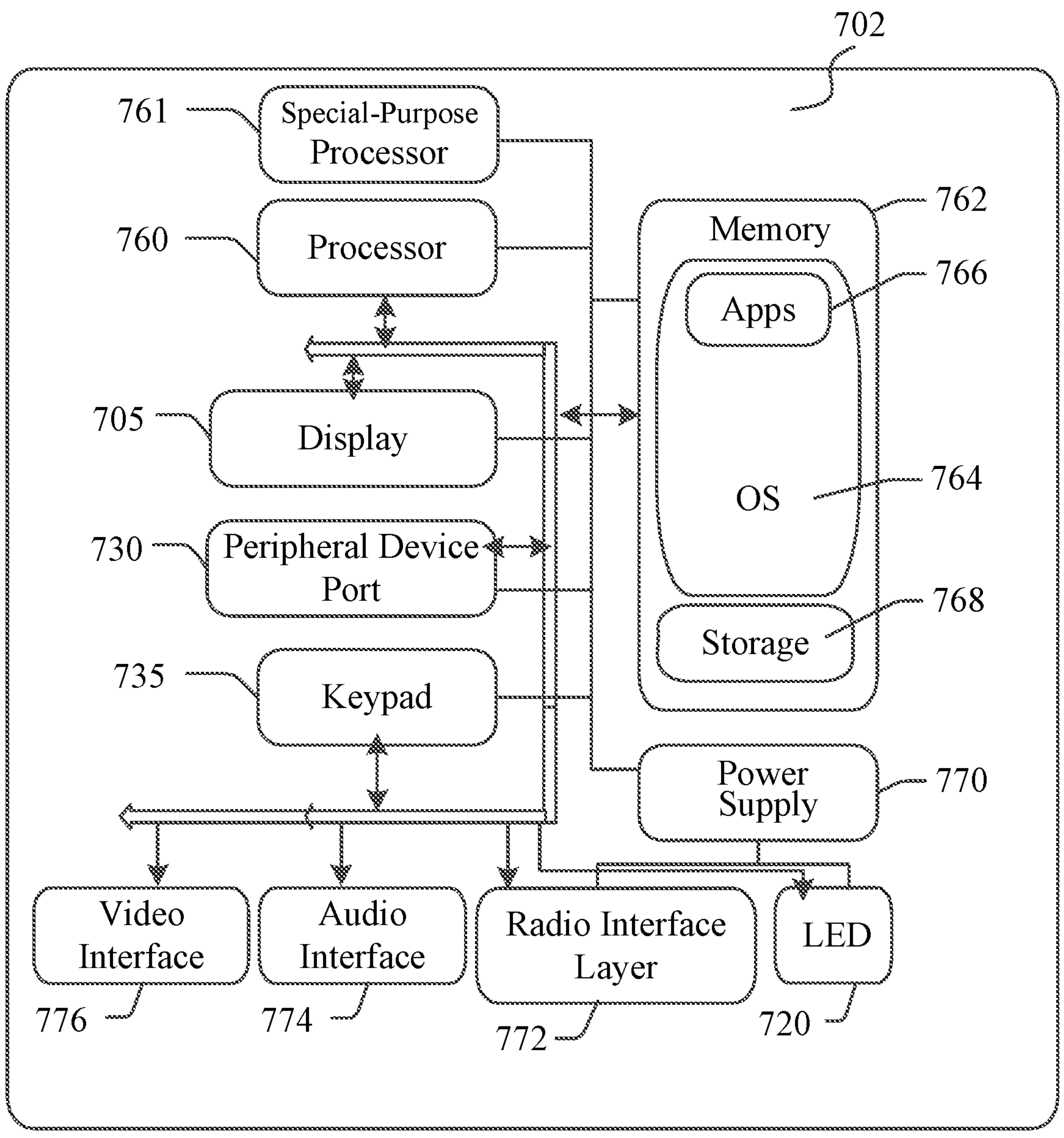

702
761
Special-Purpose Processor
760
Processor
762
Memory
766
Apps
705
Display
764
OS
730
Peripheral Device Port
768
Storage
735
Keypad
770
Power Supply
Video Interface
Audio Interface
Radio Interface Layer
LED
776
774
772
720

FIG. 7B

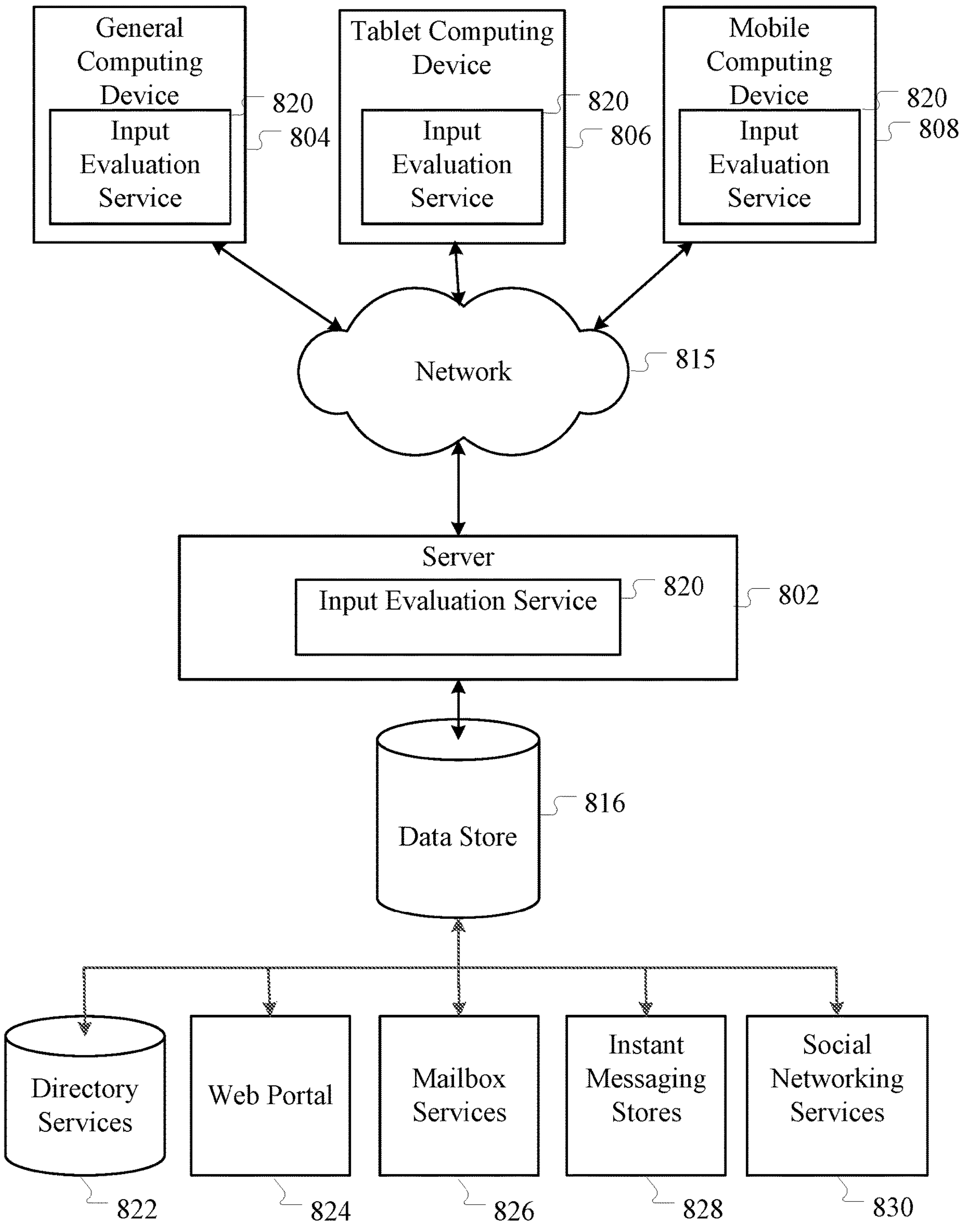

General Computing Device
Input Evaluation Service
820
804
Tablet Computing Device
Input Evaluation Service
820
806
Mobile Computing Device
Input Evaluation Service
820
808
Network
815
Server
Input Evaluation Service
820
802
Data Store
816
Directory Services
822
Web Portal
824
Mailbox Services
826
Instant Messaging Stores
828
Social Networking Services
830

FIG. 8

TRANSMIT SIDE SCALING AND ALIGNMENT

BACKGROUND

Receive side scaling enables an operating system to specify to a network interface card the manner in which data packets received by the network interface card are to be distributed among the processors of the operating system. However, there is currently no mechanism for transmit side scaling, in which the network interface card specifies to the operating system the manner in which data packets transmitted by the operating system are to be distributed to the network interface card. Further, there is currently no mechanism to align the receive side scaling and the transmit side scaling.

It is with respect to these and other general considerations that the aspects disclosed herein have been made. Also, although relatively specific problems may be discussed, it should be understood that the examples should not be limited to solving the specific problems identified in the background or elsewhere in this disclosure.

SUMMARY

Examples of the present disclosure describe systems and methods for transmit side scaling. In examples, transmission side configuration information is received by a host operating system from a guest operating system, where the transmission side scaling configuration information specifies the manner in which data packets transmitted by the host operating system are to be distributed to a network interface card of the host operating system. The transmission side configuration scaling information is implemented in an outbound transmission table of the host operating system. When a data packet is received by the host operating system, the host operating system evaluates the data packet using the outbound transmission table. Based on the evaluation, that data packet is transmitted using a specified transmit queue of the network interface card.

Examples of the present disclosure further describe systems and methods for aligning receive side scaling and transmit side scaling. In examples, a host operating system constructs an inbound transmission table that comprises a mapping of data packet information to processors of the host operating system. The host operating system provides the inbound transmission table to a network interface card to be stored. When a data packet is received by the network interface card, the network interface card evaluates the data packet using the inbound transmission table. Based on the evaluation, the network interface card transmits the data packet to a specified processor of the host operating system and the data packet is transmitted using the specified processor to a corresponding transmit queue of another network interface card.

This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter. Additional aspects, features, and/or advantages of examples will be set forth in part in the description which follows and, in part, will be apparent from the description, or may be learned by practice of the disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

Examples are described with reference to the following figures.

FIG. **1** illustrates an overview of an example host device for TSS and TSS/RSS alignment.

FIGS. **2**A and **2**B illustrate an example computing environment for implementing TSS.

FIG. **3** illustrates an example computing environment for aligning RSS and TSS.

FIG. **4** illustrates an example method for providing a TSS solution.

FIG. **5** illustrates an example method for aligning RSS and TSS.

FIG. **6** is a block diagram illustrating example physical components of a computing device for practicing aspects of the disclosure.

FIGS. **7**A and **7**B are simplified block diagrams of an example mobile computing device for practicing aspects of the present disclosure.

FIG. **8** is a simplified block diagram of an example distributed computing system for practicing aspects of the present disclosure.

DETAILED DESCRIPTION

Receive side scaling (RSS) is a network driver technology that enables the efficient distribution of network-received data packets in multiprocessor systems. RSS enables an operating system (OS) to specify to a network interface card (NIC) the manner in which data packets received by the NIC are to be distributed among the central processing units (CPUs) of the operating system. RSS ensures that data packets in the same data flow are provided to the same CPU for processing, thereby preventing data packets from being delivered to and processed by CPUs out of sequence.

Currently, there is no transmit side scaling (TSS) mechanism in which the NIC specifies to the OS the manner in which data packets transmitted by the OS are to be distributed to the NIC. Instead, the OS randomly assigns data packets to the transmit queues of the NIC and the NIC multiplexes and requeues the data packets on different transmit queues as necessary. A transmit queue, as used herein, is a data structure implemented in a NIC and used to sequentially transmit data packets from the NIC to a destination. The requeuing of data packets causes processing latency, additional memory consumption, and increases data packet drops (e.g., lost or failed data packet transmissions).

Additionally, there is currently no mechanism for aligning RSS and TSS to enable data packets received via RSS to be transmitted in accordance with a TSS configuration. Instead, even if a TSS mechanism was implemented by an OS, the CPUs specified by the OS to receive the data packets from the NIC may not process the same data packet types as the transmission queues associated with the CPUs. For example, RSS may be used to specify that CPU **1** of an OS is to be used to receive a certain type of data packet. TSS may be used to specify that transmit queue **3** of the OS's NIC is to be used to transmit the certain type of data packet. If CPU **1** is not aligned to transmit queue **3** (e.g., if CPU **1** is aligned to transmit queue **1** and CPU **3** is aligned to transmit queue **3**), it may be necessary for the NIC to requeue the data packet when the data packet is received from the OS.

Accordingly, the present disclosure describes systems and methods for providing a TSS solution. In examples, TSS configuration information is received by a host OS from an alternative OS (e.g., a guest OS or the OS of a remote computing device or computing system). The TSS configuration information specifies the manner in which data packets transmitted by the host OS are to be distributed to a NIC of the host OS such that the NIC transmits the data packet to the alternative OS in a particular manner. For example, a guest OS may specify that certain data packets are transmitted to a particular virtual CPU of the guest OS. The TSS configuration information includes data packet information and transmit queue information. In examples, the data packet information relates to a type of data packet (e.g., raw Internet protocol (IP), Internet control message protocol (ICMP), user datagram protocol (UDP), transmission control protocol (TCP)) and/or one or more header fields of a data packet (e.g., IP version, source IP address, destination IP address, time-to-live, network traffic class, flow label, payload length). The transmit queue information comprises transmit queue identifiers (e.g., a queue number or queue label).

The TSS configuration information is implemented in an outbound transmission data structure of the host OS, such as a data table, an index, or a list (collectively referred to herein as "outbound transmission table"). In some examples, TSS configuration information is implemented in a NIC of the host OS. The NIC may be a physical NIC or a virtual NIC. In other examples, the TSS configuration information is not implemented in a NIC. Implementing the TSS configuration information comprises applying a hash function to the data packet information to compute hash values. The hash values and the transmit queue information are stored in an outbound transmission table. In one example, only a portion of the hash value, such as the least significant bits of the hash value, is stored with the transmit queue information. In some examples, a hash function is not applied to the data packet information and the un-hashed data packet information is stored along with the transmit queue information in the outbound transmission table.

When a data packet intended for the alternative OS is received by the host OS or generated by the host OS, the host OS evaluates the data packet using the outbound transmission table. As part of the evaluation, the host OS performs a lookup of the data packet information of the data packet using a data structure that maps data packet information to hash values, such as a lookup table. The hash value for the data packet is compared to the hash values in the outbound transmission table to determine a transmit queue to be used to transmit the data packet. In examples in which the outbound transmission table does not store hash values, the NIC compares the data packet information of the data packet to data packet information stored in the outbound transmission table. The NIC then transmits the data packet to the alternative OS using the determined transmit queue.

The present disclosure also provides systems and methods for aligning RSS and TSS. In examples, a host operating system constructs an inbound transmission data structure, such as a data table, an index, or a list (collectively referred to herein as "inbound transmission table"), that comprises RSS configuration information. The RSS configuration information specifies the manner in which data packets transmitted to the host OS are to be distributed to the CPUs of the host OS. For example, a host OS may specify that certain data packets are transmitted to a particular CPU of the host OS. The RSS configuration information includes data packet information, as described above, and CPU information. The CPU information comprises CPU identifiers (e.g., a CPU number or CPU label).

The host OS constructs the inbound transmission table such that the RSS configuration information is aligned to TSS configuration information stored by the host OS. As one example, the RSS configuration information may specify that a certain data packet type is to be transmitted to a particular physical CPU of the host OS. The TSS configuration information may specify that the certain data packet type is to be transmitted to a particular virtual CPU of a guest OS using a particular transmit queue of the host OS's NIC. Accordingly, the host OS constructs the inbound transmission table such that the CPU for receiving the certain data packet type is aligned with the transmit queue for transmitting the certain data packet type. In examples, aligning RSS configuration information to TSS configuration information comprises storing a mapping of CPUs of the host OS to transmit queues of the NIC.

The host OS provides the inbound transmission table to a NIC of the host OS. The NIC may be a physical NIC or a virtual NIC. The NIC implements the inbound transmission table. Implementing the inbound transmission table may comprise applying a hash function to the data packet information within the inbound transmission table, as described above.

When a data packet intended for an alternative OS accessible to the host OS is received by the NIC, the NIC evaluates the data packet using the inbound transmission table. The evaluation may comprise computing a hash value for the data packet information or performing a lookup of the data packet information, as described above. Based on the evaluation, the NIC transmits the data packet to a specified CPU of the host OS. The specified CPU transmits the data packet to a transmit queue aligned to the specified CPU. The NIC (or a different NIC of the host OS) then transmits the data packet to the alternative OS using the determined transmit queue. Thus, the host OS does not need to requeue the data packet in order to transmit the data packet to the alternative OS.

Accordingly, the present disclosure provides a plurality of technical benefits and improvements over previous data transmission solutions. These technical benefits and improvements include: providing a TSS mechanism to specify the manner in which data packets transmitted by a host OS are to be distributed to transmit queues of the NIC, aligning RSS and TSS configurations to prevent unintentional requeuing of data packets, and reducing processing latency, memory consumption, and packet drops during transmission, among others.

FIG. **1** illustrates a host device for TSS and aligning RSS and TSS. Example host device **100** as presented is a combination of interdependent components that interact to form an integrated whole. Components of host device **100** may be hardware components or software components (e.g., applications, application programming interfaces (APIs), modules, VMs, or runtime libraries) implemented on and/or executed by hardware components of host device **100**. In one example, components of host device **100** are distributed across multiple processing devices.

In FIG. **1**, host device **100** comprises host physical resources **102**, host OS **104**, host applications **106**, hypervisor **108**, and VMs **110**A, **110**B, and **110**C (collectively referred to as "VM(s) **110**"). The scale and structure of devices, environments, and systems discussed herein may vary and may include additional or fewer components than those described in FIG. **1** and subsequent figures. Further, although examples in FIG. **1** and subsequent figures will be discussed in the context of VMs, the examples are equally applicable to other contexts, such as those that do not implement virtual environments or virtual components. Examples of host device **100** include personal computers (PCs), server devices, mobile devices (e.g., smartphones, tablets, laptops, personal digital assistants (PDAs)), wearable devices (e.g., smart watches, smart eyewear, fitness trackers, smart clothing, body-mounted devices, head-mounted displays), gaming consoles or devices, and Internet of Things (IoT) devices.

Host physical resources **102** include processing hardware (e.g., a central processing unit (CPU), a graphics processing unit (GPU), a video card), memory, persistent storage, network interfaces (e.g., physical NICs and virtual NICs), and the like. In examples, host physical resources **102** are directly accessible by host OS **104**, host applications **106**, and hypervisor **108**, and are not directly accessible by VM(s) **110**. Instead, VM(s) **110** indirectly access host physical resources **102** via a component of host device **100**, such as hypervisor **108**.

Host OS **104** provides software for performing various computing functions, such as executing host applications **106**, executing hypervisor **108**, scheduling tasks, and controlling peripherals (e.g., microphones, touch-based sensors, geolocation sensors, accelerometers, optical/magnetic sensors, gyroscopes, keyboards, and pointing/selection tools). Host OS **104** is configured to receive input data (e.g., audio input, touch input, text-based input, gesture input, and/or image input) from a user or a computing device. In some examples, the input data corresponds to user interaction with host applications **106** or hypervisor **108**. In other examples, the input data corresponds to automated interaction with services or host applications **106**, such as the automatic (e.g., non-manual) execution of scripts or sets of commands at scheduled times or in response to predetermined events.

Host applications **106** may be implemented locally on host device **100** or accessible remotely by host device **100** via a network, such as a private area network (PAN), a local area network (LAN), a wide area network (WAN), and the like. Host applications **106** provide access to a set of software and/or hardware functionality. Examples of host applications **106** include applications and services relating to word processing, spreadsheets, presentation software, document-reading, social media software or platforms, search engines, media software or platforms, multimedia players, content design software or tools, database software or tools, provisioning software, and alert or notification software.

Hypervisor **108** is software that creates, executes, and manages VM(s) **110** within an execution environment of host device **100**. Hypervisor **108** exposes VM(s) **110** to one or more networks in order to enable VM(s) **110** to communicate amongst each other and to communicate with other devices or components of or external to host device **100**. In examples, hypervisor **108** provides VM(s) **110** access to host physical resources **102** and/or the physical resources of computing devices external to host device **100**.

VM(s) **110** are compute resources that use software instead of a physical computing device to execute and deploy applications. VM(s) **110** comprise guest OS **112**A, **112**B, and **112**C (collectively referred to as "guest OS **112**"). Each guest OS **112** comprises a kernel space and a user space. The kernel space is reserved for executing a privileged OS kernel, kernel extensions, and most device drivers. The user space is reserved for executing application software and non-privileged device drivers. In examples, guest OS **112** implements or has access to applications, such as described with respect to host applications **106**. Each guest OS **112** may comprise or provide access to a different set of applications. A set, as used herein, may comprise one or more items.

FIGS. **2**A, **2**B, and **3** illustrate a computing environment for implementing TSS and aligning RSS and TSS. In examples, the computing environment is implemented in a computing device, such as host device **100**. However, alternative implementations of the computing environment are contemplated.

FIG. **2**A illustrates a computing environment implementing TSS. Example computing environment **200** comprises host OS **202**. Host OS **202** comprises guest OS **204**, virtual NIC **206**, outbound transmission table (OTT) **208**, and physical CPUs **210**A-D. Guest OS **204** comprises virtual CPUs **212**A-D. A virtual CPU represents a portion or share of a physical CPU that is assigned to a guest OS. Each of virtual CPUs **212**A-D may be configured to receive and process one or more data packet types. Virtual NIC **206** comprises transmit queues (TX Q) **214**A-D. Transmit queues **214**A-D transmit data packets to/from host OS **202** and guest OS **204**.

In FIG. **2**A, guest OS **204** is configured such that each of virtual CPUs **212**A-D is configured to process a certain data packet type. For example, virtual CPU **212**A processes a first packet data type, virtual CPU **212**B processes a second packet data type, and so on. To prevent requeuing of data packets received by virtual NIC **206** and intended for guest OS **204**, each of virtual CPUs **212**A-D is aligned to a respective one of transmit queues **214**A-D such that data packets transmitted using a transmit queue are provided directly to the virtual CPU aligned to the transmit queue. For example, transmit queue **214**A is aligned to virtual CPU **212**A, transmit queue **214**B is aligned to virtual CPU **212**B, transmit queue **214**C is aligned to virtual CPU **212**C, and transmit queue **214**D is aligned to virtual CPU **212**D.

Outbound transmission table **208** comprises TSS configuration information received from guest OS **204**. The TSS configuration information specifies the manner in which data packets transmitted by physical CPUs **210**A-D to guest OS **204** are to be distributed to transmit queues **214**A-D. As one example, outbound transmission table **208** specifies that a first data packet type is to be transmitted to transmit queue **214**A, a second data packet type is to be transmitted to transmit queue **214**B, a third data packet type is to be transmitted to transmit queues **214**C, and a fourth data packet type is to be transmitted to transmit queues **214**D. In some examples, multiple data packet types may be transmitted to each of transmit queues **214**A-D and the same data packet type may be transmitted to two or more of transmit queues **214**A-D.

In some examples, outbound transmission table **208** comprises TSS configuration information for multiple NICs. For example, in FIG. **2**B, computing environment **200** further comprises physical NIC **216**. Physical NIC **216** comprises transmit queues **218**A-D. Outbound transmission table **208** comprises TSS configuration information for virtual NIC **206** and physical NIC **216**. The TSS configuration information for the physical NIC specifies the manner in which data packets transmitted by physical CPUs **210**A-D to a remote computing device or computing system are to be distributed to transmit queues **218**A-D.

FIG. **3** illustrates a computing environment implementing alignment of RSS and TSS. In FIG. **3**, physical NIC **216** further comprises inbound transmission table **220**. Inbound transmission table (ITT) **220** comprises RSS configuration information received from host OS **202**. The RSS configuration information specifies the manner in which data packets received by host OS **202** are to be distributed to physical CPUs **210**A-D. As one example, inbound transmission table **220** specifies that a first data packet type is to be transmitted to physical CPU **210**A using transmit queue **218**A, a second data packet type is to be transmitted to physical CPU **210**B using transmit queue **218**B, a third data packet type is to be transmitted to physical CPU **210**C using transmit queue **218**C, and a fourth data packet type is to be transmitted to physical CPU **210**D using transmit queue **218**D. In some examples, multiple data packet types may be transmitted to each of physical CPUs **210**A-D and the same data packet type may be transmitted to two or more of physical CPUs **210**A-D.

In FIG. **3**, host OS **202** is configured such that the RSS configuration information in inbound transmission table **220** is aligned with the TSS configuration information in outbound transmission table **208**. Continuing from the above example, physical CPU **210**A is aligned to transmit queue **214**A, physical CPU **210**B is aligned to transmit queue **214**B, physical CPU **210**C is aligned to transmit queue **214**C, and physical CPU **210**D is aligned to transmit queue **214**D. Accordingly, data packets received by physical NIC **216** can be transmitted between physical CPUs **210**A-D and virtual CPUs **212**A-D such that the data packet need not be requeued to be sent to a different one of physical CPUs **210**A-D or to a different one of virtual CPUs **212**A-D.

Having described one or more devices and systems that may employ aspects of the present disclosure, methods for performing these aspects will now be described. In examples, methods **400** and **500** may be executed by a device, such as host device **100**, or a computing environment, such as computing environment **200** of FIGS. **2**A, **2**B, and **3**. However, methods **400** and **500** are not limited to such examples.

FIG. **4** illustrates an example method for providing a TSS solution. Example method **400** begins at operation **402**, where TSS configuration information is received by a host OS, such as host OS **202**. The TSS configuration information may be provided by a guest OS, such as guest OS **204**, or by an alternative OS of a remote computing device or computing system. The TSS configuration information specifies the manner in which data packets transmitted by the host OS are to be distributed to a NIC of the host OS, such as virtual NIC **206** or physical NIC **216**. In one example, the TSS configuration information specifies data packet types (e.g., raw IP, ICMP, UDP, TCP) to be distributed to each transmit queue of the NIC. Alternatively, the TSS configuration information may specify data packet header fields to be used to distribute data packets to each transmit queue of the NIC.

At operation **404**, the TSS configuration information is implemented in an outbound transmission table, such as outbound transmission table **208**. In examples, implementing the TSS configuration information comprises applying a hash function to data packet header fields or other data packet information to compute hash values. The hash values (or a portion thereof) and transmit queue information are stored in the outbound transmission table such that the hash values are correlated to specific transmit queues of a NIC, such as transmit queues **214**A-D and **218**A-D. As a specific example, a hash value for raw IP data packets is correlated to (e.g., mapped to) transmit queue **1** of a virtual NIC, a hash value for ICMP data packets is correlated to transmit queue **2** of the virtual NIC, and so on.

At operation **406**, a data packet is received by the host OS. The data packet may be intended for the guest OS and may be generated by the host OS are received via the NIC. In examples, the data packet is received by a physical CPU of the host OS, such as physical CPUs **210**A-D. The data packet is of a data packet type and comprises data packet information, such as a header section and a body section. The header section comprises header fields and the body section comprises a payload (e.g., the part of the data packet that is intended as the actual message).

At operation **408**, the data packet is evaluated using the outbound transmission table. In examples, evaluating the data packet comprises providing, by the host OS, the data packet to the NIC. The NIC computes a hash value for the data packet information of the data packet or performs a lookup of the data packet information using a data structure that maps data packet information to hash values, such as a lookup table. The hash value for the data packet is compared to the hash values in the outbound transmission table to determine a transmit queue to be used to transmit the data packet to the guest OS. In at least one example, the outbound transmission table comprises data packet information, instead of or in addition to, hash values for the data packet information. In such an example, evaluating the outbound transmission table comprises performing a lookup of the data packet information of the data packet, as described above.

At operation **410**, the data packet is transmitted to the guest OS using the determined transmit queue. In examples, the determined transmit queue is aligned to a virtual CPU of the guest OS, such as one or more of virtual CPUs **212**A-D. Each virtual CPU may be configured to process a specific data packet type, in accordance with the TSS configuration information provided to the host OS by the guest OS. As a specific example, a first virtual CPU is configured to receive raw IP data packets, a second virtual CPU is configured to receive ICMP data packets, and so on.

FIG. **5** illustrates an example method for aligning RSS and TSS. Example method **500** begins at operation **502**, where a host OS, such as host OS **202**, constructs an inbound transmission table, such as inbound transmission table **220**. The inbound transmission table is constructed based on RSS configuration information for the host OS and TSS configuration information provided by a guest OS, such as guest OS **204**, or by an alternative OS of a remote computing device or computing system. The RSS configuration information specifies the manner in which data packets transmitted to the host OS are to be distributed to the CPUs of the host OS, whereas the TSS configuration information specifies the manner in which data packets transmitted by the host OS are to be distributed to a NIC of the host OS.

The host OS constructs the inbound transmission table such that the RSS configuration information is aligned to TSS configuration information. As one example, the TSS configuration information may specify that a certain data packet type (e.g., raw IP, ICMP, UDP, TCP) is to be transmitted to a particular virtual CPU of a guest OS using a particular transmit queue of a NIC, such as virtual NIC **206** or physical NIC **216**. The RSS configuration information may specify that the certain data packet type is to be received by to a particular physical CPU of the hot OS, such as physical CPUs **210**A-D. Accordingly, the host OS constructs the inbound transmission table such that the particular physical CPU is aligned to the particular transmit queue of the NIC. In some examples, inbound transmission table stores a mapping of physical CPUs to transmit queues.

At operation **504**, the host OS provides the inbound transmission table to the NIC. The NIC may store the inbound transmission table as a new data table. Alternatively, the NIC may use the inbound transmission table to update an existing table. As one example, the NIC may comprise a data table including previously received RSS configuration information. The data table may be an indirection table that represents a mapping between hash values and transmit queue information. The indirection table may be indexed using a number of least significant bits of a set of hash values corresponding to data packet information. In such an example, the NIC updates the mappings in the indirection table with the correlations/mappings in the inbound transmission table.

At operation **506**, physical CPU of the host OS receives a data packet based on the inbound transmission table. The data packet may be intended for the guest OS and may be received via the NIC. The data packet is of a data packet type comprises data packet information, as described with respect to operation **406** of FIG. **4**.

At operation **508**, the data packet is transmitted to a transmit queue aligned to the physical CPU. In examples, the transmit queue is aligned to the physical CPU in accordance with the inbound transmission table. As a specific example, the transmit queue and the physical CPU are both configured to receive and transmit the same data packet type (e.g., the data packet type of the received data packet). Accordingly, the physical CPU transmits the data packet to the transmit queue and the transmit queue transmits the data packet to a virtual CPU of the guest OS, where the virtual CPU is configured to receive and transmit the data packet type of the received data packet.

FIGS. **6-9** and the associated descriptions provide a discussion of a variety of operating environments in which aspects of the disclosure may be practiced. However, the devices and systems illustrated and discussed with respect to FIGS. **6-9** are for purposes of example and illustration, and, as is understood, a vast number of computing device configurations may be utilized for practicing aspects of the disclosure, described herein.

FIG. **6** is a block diagram illustrating physical components (e.g., hardware) of a computing device **600** with which aspects of the disclosure may be practiced. The computing device components described below are suitable for the computing devices and systems described above. In a basic configuration, the computing device **600** includes a processing system **602** comprising at least one processing unit and a system memory **604**. Depending on the configuration and type of computing device, the system memory **604** may comprise volatile storage (e.g., random access memory), non-volatile storage (e.g., read-only memory), flash memory, or any combination of such memories.

The system memory **604** includes an operating system **605** and one or more program modules **606** suitable for running software application **620**, such as one or more components supported by the systems described herein. The operating system **605**, for example, is suitable for controlling the operation of the computing device **600**.

Furthermore, embodiments of the disclosure may be practiced in conjunction with a graphics library, other operating systems, or any other application program. This basic configuration is illustrated in FIG. **6** by those components within a dashed line **608**. The computing device **600** may have additional features or functionality. For example, the computing device **600** may include additional data storage devices (removable and/or non-removable) such as, for example, magnetic disks, optical disks, tape, and other computer readable media. Such additional storage is illustrated in FIG. **6** by a removable storage device **607** and a non-removable storage device **610**.

The term computer readable media as used herein includes computer storage media. Computer storage media includes volatile and nonvolatile, removable and non-removable media implemented in any method or technology for storage of information, such as computer readable instructions, data structures, or program modules. The system memory **604**, the removable storage device **607**, and the non-removable storage device **610** are all computer storage

media examples (e.g., memory storage). Computer storage media includes random access memory (RAM), read-only memory (ROM), electrically erasable ROM (EEPROM), flash memory or other memory technology, CD-ROM, digital versatile disks (DVD) or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other article of manufacture which can be used to store information and which can be accessed by the computing device **600**. Any such computer storage media may be part of the computing device **600**. Computer storage media does not include a carrier wave or other propagated or modulated data signal.

Communication media may be embodied by computer readable instructions, data structures, program modules, or other data in a modulated data signal, such as a carrier wave or other transport mechanism, and includes any information delivery media. The term "modulated data signal" describes a signal that has one or more characteristics set or changed in such a manner as to encode information in the signal. By way of example, communication media includes wired media such as a wired network or direct-wired connection, and wireless media such as acoustic, RF, infrared, and other wireless media.

As stated above, a number of program modules and data files may be stored in the system memory **604**. While executing on the processing system **602**, the program modules **606** (e.g., application **620**) perform processes including the aspects, as described herein. Other program modules that may be used in accordance with aspects of the present disclosure may include electronic mail and contacts applications, word processing applications, spreadsheet applications, database applications, slide presentation applications, drawing or computer-aided application programs, etc.

Furthermore, embodiments of the disclosure may be practiced in an electrical circuit comprising discrete electronic elements, packaged or integrated electronic chips containing logic gates, a circuit utilizing a microprocessor, or on a single chip containing electronic elements or microprocessors. For example, embodiments of the disclosure may be practiced via a system-on-a-chip (SOC) where each or many of the components illustrated in FIG. **6** are integrated onto a single integrated circuit. Such an SOC device may include one or more processing units, graphics units, communications units, system virtualization units and various application functionality all of which are integrated (or "burned") onto the chip substrate as a single integrated circuit. When operating via an SOC, the functionality, described herein, with respect to the capability of client to switch protocols may be operated via application-specific logic integrated with other components of the computing device **600** on the single integrated circuit (chip). Embodiments of the disclosure may also be practiced using other technologies capable of performing logical operations such as, for example, AND, OR, and NOT, including mechanical, optical, fluidic, and quantum technologies. In addition, embodiments of the disclosure may be practiced within a general-purpose computer or in any other circuits or systems.

The computing device **600** may also have one or more input device(s) **612** such as a keyboard, a mouse, a pen, a sound or voice input device, a touch or swipe input device, etc. Output device(s) **614** such as a display, speakers, a printer, etc. may also be included. The aforementioned devices are examples and others may be used. The computing device **600** includes one or more communication connections **616** allowing communications with other computing devices **640**. Examples of suitable communication connections **616** include radio frequency (RF) transmitter, receiver, and/or transceiver circuitry; universal serial bus (USB), parallel, and/or serial ports.

FIGS. **7**A and **7**B illustrate a mobile computing device **700**, for example, a mobile telephone (e.g., a smart phone), wearable computer (such as a smart watch), a tablet computer, a laptop computer, and the like, with which embodiments of the disclosure may be practiced. In some aspects, the client device is a mobile computing device. With reference to FIG. **7**A, one aspect of a mobile computing device **700** for implementing the aspects is illustrated. In a basic configuration, the mobile computing device **700** is a handheld computer having both input elements and output elements. The mobile computing device **700** typically includes a display **705** and one or more input buttons **710** that allow the user to enter information into the mobile computing device **700**. The display **705** of the mobile computing device **700** may also function as an input device (e.g., a touch screen display).

If included, an optional side input element **715** allows further user input. The side input element **715** may be a rotary switch, a button, or any other type of manual input element. In alternative aspects, mobile computing device **700** incorporates more or less input elements. For example, the display **705** may not be a touch screen in some embodiments.

In yet another alternative embodiment, the mobile computing device **700** is a mobile telephone, such as a cellular phone. The mobile computing device **700** may also include an optional keypad **735**. Optional keypad **735** is a physical keypad or a "soft" keypad generated on the touch screen display.

In various embodiments, the output elements include the display **705** for showing a graphical user interface (GUI), a visual indicator **720** (e.g., a light emitting diode), and/or an audio transducer **725** (e.g., a speaker). In some aspects, the mobile computing device **700** incorporates a vibration transducer for providing the user with tactile feedback. In yet another aspect, the mobile computing device **700** incorporates input and/or output ports, such as an audio input (e.g., a microphone jack), an audio output (e.g., a headphone jack), and a video output (e.g., a HDMI port) for sending signals to or receiving signals from an external device.

FIG. **7**B is a block diagram illustrating the architecture of one aspect of a mobile computing device. That is, the mobile computing device can incorporate a system (e.g., an architecture) **702** to implement some aspects. In one embodiment, the system **702** is implemented as a "smart phone" capable of running one or more applications (e.g., browser, e-mail, calendaring, contact managers, messaging clients, games, and media clients/players). In some aspects, the system **702** is integrated as a computing device, such as an integrated personal digital assistant (PDA) and wireless phone.

One or more application programs **766** may be loaded into the memory **762** and run on or in association with the operating system (OS) **764**. Examples of the application programs include phone dialer programs, e-mail programs, personal information management (PIM) programs, word processing programs, spreadsheet programs, Internet browser programs, messaging programs, and so forth. The system **702** also includes a non-volatile storage area **768** within the memory **762**. The non-volatile storage area **768** is used to store persistent information that should not be lost if the system **702** is powered down. The application programs **766** may use and store information in the non-volatile storage area **768**, such as e-mail or other messages used by an e-mail application, and the like. A synchronization application (not shown) also resides on the system **702** and is programmed to interact with a corresponding synchronization application resident on a host computer to keep the information stored in the non-volatile storage area **768** synchronized with corresponding information stored at the host computer. As should be appreciated, other applications may be loaded into the memory **762** and run on the mobile computing device described herein (e.g., search engine, extractor module, relevancy ranking module, answer scoring module).

The system **702** has a power supply **770**, which may be implemented as one or more batteries. The power supply **770** might further include an external power source, such as an AC adapter or a powered docking cradle that supplements or recharges the batteries.

The system **702** also includes a radio interface layer **772** that performs the function of transmitting and receiving radio frequency communications. The radio interface layer **772** facilitates wireless connectivity between the system **702** and the "outside world," via a communications carrier or service provider. Transmissions to and from the radio interface layer **772** are conducted under control of the operating system **764**. In other words, communications received by the radio interface layer **772** are disseminated to the application programs **766** via the OS **764**, and vice versa.

The visual indicator (e.g., light emitting diode (LED) **720**) is used to provide visual notifications, and/or an audio interface **774** is used for producing audible notifications via the audio transducer **725**. In the illustrated embodiment, the visual indicator **720** is a light emitting diode (LED) and the audio transducer **725** is a speaker. These devices may be directly coupled to the power supply **770** so that when activated, they remain on for a duration dictated by the notification mechanism even though the processor(s) (e.g., processor **760** and/or special-purpose processor **761**) and other components might shut down for conserving battery power. The LED may be programmed to remain on indefinitely until the user takes action to indicate the powered-on status of the device. The audio interface **774** is used to provide audible signals to and receive audible signals from the user. For example, in addition to being coupled to the audio transducer **725**, the audio interface **774** may also be coupled to a microphone to receive audible input, such as to facilitate a telephone conversation. In accordance with embodiments of the present disclosure, the microphone also serves as an audio sensor to facilitate control of notifications, as will be described below. The system **702** further includes a video interface **776** that enables an operation of a peripheral device port **730** (e.g., an on-board camera) to record still images, video stream, and the like.

A mobile computing device **700** implementing the system **702** may have additional features or functionality. For example, the mobile computing device **700** may also include additional data storage devices (removable and/or non-removable) such as, magnetic disks, optical disks, or tape. Such additional storage is illustrated in FIG. **7**B by the non-volatile storage area **768**.

Data/information generated or captured by the mobile computing device **700** and stored via the system **702** may be stored locally on the mobile computing device **700**, as described above, or the data may be stored on any number of storage media that may be accessed by the device via the radio interface layer **772** or via a wired connection between the mobile computing device **700** and a separate computing device associated with the mobile computing device **700**, for example, a server computer in a distributed computing network, such as the Internet. As should be appreciated such data/information may be accessed via the mobile computing device **700** via the radio interface layer **772** or via a distributed computing network. Similarly, such data may be readily transferred between computing devices for storage and use according to well-known data transfer and storage means, including electronic mail and collaborative data sharing systems.

FIG. **8** illustrates one aspect of the architecture of a system for processing data received at a computing system from a remote source, such as a personal computer **804**, tablet computing device **806**, or mobile computing device **808**, as described above. Content displayed at server device **802** may be stored in different communication channels or other storage types. For example, various documents may be stored using directory services **822**, web portals **824**, mailbox services **826**, instant messaging stores **828**, or social networking services **830**.

An input evaluation service **820** may be employed by a client that communicates with server device **802**, and/or input evaluation service **820** may be employed by server device **802**. The server device **802** provides data to and from a client computing device such as a personal computer **804**, a tablet computing device **806** and/or a mobile computing device **808** (e.g., a smart phone) through a network **815**. By way of example, the computer system described above may be embodied in a personal computer **804**, a tablet computing device **806** and/or a mobile computing device **808** (e.g., a smart phone). Any of these embodiments of the computing devices may obtain content from the data store **816**, in addition to receiving graphical data useable to be either pre-processed at a graphic-originating system, or post-processed at a receiving computing system.

As will be understood from the foregoing disclosure, one example of the technology relates to a computer-implemented method. The method comprises: receiving, at a host operating system (OS), a guest transmission configuration from a guest OS; implementing, at the host OS, the guest transmission configuration in an outbound transmission table; receiving a data packet at the host OS; determining a transmission queue for transmitting the data packet to the guest OS by evaluating the data packet using the outbound transmission table; and transmitting the data packet to the guest OS using the transmission queue.

In another example, the technology relates to as alternative computer-implemented method. The method comprises: constructing, by a host operating system (OS), an inbound transmission table that comprises a mapping of data packet types to a set of processors of the host OS; providing the inbound transmission table to a network interface card (NIC); receiving, at a processor of the set of processors, a data packet based on the mapping; and transmitting the data packet to a transmission queue associated with a guest operating system (OS), wherein the processor is aligned to the transmission queue.

In another example, the technology relates to a system comprising: a processor system; and memory coupled to the processor system, the memory comprising computer executable instructions that, when executed by the processor system, perform operations comprising: receiving, at a host operating system (OS), a transmit side scaling (TSS) transmission configuration from a guest OS; implementing, at the host OS, the TSS transmission configuration in an outbound transmission table; receiving a data packet at the host OS, wherein the data packet is intended for the guest OS; determining a transmission queue correlated to header data stored in an outbound transmission table by matching header data associated with the data packet with the header data stored in the outbound transmission table; and transmitting the data packet to the guest OS using the transmission queue.

Aspects of the present disclosure, for example, are described above with reference to block diagrams and/or operational illustrations of methods, systems, and computer program products according to aspects of the disclosure. The functions/acts noted in the blocks may occur out of the order as shown in any flowchart. For example, two blocks shown in succession may in fact be executed substantially concurrently or the blocks may sometimes be executed in the reverse order, depending upon the functionality/acts involved.

The description and illustration of one or more aspects provided in this application are not intended to limit or restrict the scope of the disclosure as claimed in any way. The aspects, examples, and details provided in this application are considered sufficient to convey possession and enable others to make and use the best mode of claimed disclosure. The claimed disclosure should not be construed as being limited to any aspect, example, or detail provided in this application. Regardless of whether shown and described in combination or separately, the various features (both structural and methodological) are intended to be selectively included or omitted to produce an embodiment with a particular set of features. Having been provided with the description and illustration of the present application, one skilled in the art may envision variations, modifications, and alternate aspects falling within the spirit of the broader aspects of the general inventive concept embodied in this application that do not depart from the broader scope of the claimed disclosure.

What is claimed is:

1. A method comprising:

receiving, at a host operating system (OS), a guest transmission configuration from a guest OS;

implementing, at the host OS, the guest transmission configuration in an outbound transmission table;

receiving a data packet at the host OS;

determining a transmission queue for transmitting the data packet to the guest OS by evaluating the data packet using the outbound transmission table; and

transmitting the data packet to the guest OS using the transmission queue.

2. The method of claim **1**, wherein the guest transmission configuration comprises data packet information that is associated with data packet type.

3. The method of claim **2**, wherein the guest transmission configuration further comprises a set of transmission queues for transmitting data packets to the guest OS.

4. The method of claim **3**, wherein each transmission queue in the set of transmission queues is aligned to a processor of the guest OS.

5. The method of claim **3**, wherein the data packet information associated with each data packet type is correlated to a corresponding transmission queue in the set of transmission queues.

6. The method of claim **5**, wherein implementing the guest transmission configuration further comprises:

creating a hash value for each data packet type; and

storing each hash value and the corresponding transmission queue correlated to the hash value in the outbound transmission table such that the hash value is mapped to the corresponding transmission queue.

7. The method of claim **1**, wherein receiving the data packet at the host OS comprises receiving the data packet via a physical network interface card of the host OS, wherein the data packet is intended for the guest OS.

8. The method of claim **1**, wherein evaluating the data packet using the outbound transmission table comprises:

matching a hash value of the data packet to a hash value stored in the outbound transmission table;

identifying the transmission queue as being correlated to the hash value stored in the outbound transmission table; and

determining the transmission queue based on the transmission queue being correlated to the hash value.

9. The method of claim **8**, wherein matching the hash value of the data packet to the hash value stored in the outbound transmission table comprises:

identifying a set of fields in a header of the data packet;

applying hashing function to the set of fields to generate the hash value.

10. The method of claim **1**, wherein transmitting the data packet to the guest OS using the transmission queue comprises:

identifying a first processor in a set of processors of the guest OS, wherein the first processor is aligned with the transmission queue and a second processor in the set of processors of the guest OS is not aligned to the transmission queue; and

transmitting the data packet to the guest OS such that the data packet is provided to the first processor.

11. The method of claim **1**, wherein the outbound transmission table is an indirection table.

12. The method of claim **11**, wherein the indirection table is indexed using a number of least significant bits of a set of hash values.

13. The method of claim **1**, wherein the guest transmission configuration is received from a virtual network interface card of the guest OS.

14. The method of claim **1**, wherein the host OS is implemented in a host device comprising the guest OS, the guest OS corresponding to a virtual machine.

15. A method comprising:

constructing, by a host operating system (OS), an inbound transmission table that comprises a mapping of data packet types to a set of processors of the host OS;

providing the inbound transmission table to a network interface card (NIC);

receiving, at a processor of the set of processors, a data packet based on the mapping; and

transmitting the data packet to a transmission queue associated with a guest operating system (OS), wherein the processor is aligned to the transmission queue.

16. The method of claim **11**, wherein constructing the inbound transmission table comprises:

creating a hash value for each of the data packet types;

correlating each hash value to a processor of the set of processors; and

storing each hash value and the processor correlated to the hash value in the inbound transmission table.

17. The method of claim **11**, wherein:

the host OS comprises a set of transmission queues for transmitting data packets to the guest OS, the set of transmission queues comprising the transmission queue; and

each transmission queue of the set of transmission queues is aligned to a corresponding processor of the set of processors.

18. The method of claim **17**, wherein each transmission queue of the set of transmission queues is further aligned to a corresponding processor of the guest OS.

19. The method of claim **17**, wherein each transmission queue of the set of transmission queues is aligned to the corresponding processor of the set of processors based on an indirection table of the host device, the indirection table specifying a set of data packet types and a corresponding transmission queue of the set of transmission queues for transmitting data packets having a data packet type in the set of data packet types.

20. A system comprising:

a processor system; and

memory coupled to the processor system, the memory comprising computer executable instructions that, when executed by the processor system, perform operations comprising:

receiving, at a host operating system (OS), a transmit side scaling (TSS) transmission configuration from a guest OS;

implementing, at the host OS, the TSS transmission configuration in an outbound transmission table;

receiving a data packet at the host OS, wherein the data packet is intended for the guest OS;

determining a transmission queue correlated to header data stored in an outbound transmission table by matching header data associated with the data packet with the header data stored in the outbound transmission table; and

transmitting the data packet to the guest OS using the transmission queue.

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