US009503276B2

(12) United States Patent
Ng et al.

(10) Patent No.: US 9,503,276 B2
(45) Date of Patent: Nov. 22, 2016

(54) METHOD AND SYSTEM TO REDUCE WIRELESS NETWORK PACKETS FOR CENTRALISED LAYER TWO NETWORK

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 54 days.

(21) Appl. No.: **14/003,236**

(22) PCT Filed: **Dec. 12, 2012**

(86) PCT No.: **PCT/IB2012/057201**

§ 371 (c)(1),
(2) Date: **Sep. 5, 2013**

(87) PCT Pub. No.: **WO2014/091277**

PCT Pub. Date: **Jun. 19, 2014**

(65) **Prior Publication Data**

US 2015/0222452 A1 Aug. 6, 2015

(51) **Int. Cl.**
H04L 12/46 (2006.01)
H04L 12/64 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H04L 12/4633*** (2013.01); ***H04L 12/4641*** (2013.01); ***H04L 12/6418*** (2013.01); ***H04L 45/30*** (2013.01); ***H04L 45/66*** (2013.01); ***H04L 49/201*** (2013.01)

(58) **Field of Classification Search**
CPC H04L 69/168; H04L 65/607; H04L 29/06027; H04L 69/04; H04L 69/16; H04L 29/12028; H04W 28/06; H04W 84/12; H04W 8/12
USPC 370/392, 401, 400, 469
See application file for complete search history.

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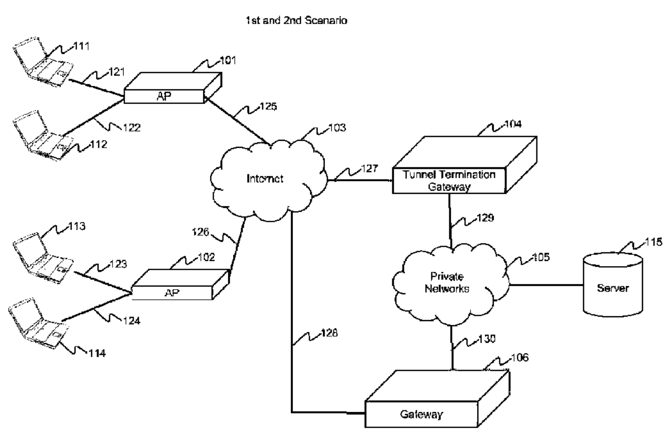
(57) **ABSTRACT**

A method of operating a communication system, comprising the steps of: receiving a first OSI layer two packet from a first network interface; determining transmission type of the first OSI layer two packet; determining whether to send a second OSI layer two packet according to the transmission type, origin and destination of the first OSI layer two packet; determining destination address and transmission type of the second OSI layer two packet when determined to send the second OSI layer two packet; and sending the second OSI layer two packet through a second network interface when determined to send the second OSI layer two packet; wherein when the first OSI layer two packet is encapsulated in at least one layer three packet, the second OSI layer two packet is not encapsulated in any OSI layer three packet; and wherein when the first OSI layer two packet is not encapsulated in any Open Systems Interconnection (OSI) layer three packet, the second OSI layer two packet is encapsulated in at least one OSI layer three packet.

24 Claims, 4 Drawing Sheets



(51) **Int. Cl.**

H04L 12/725 (2013.01)
H04L 12/721 (2013.01)
H04L 12/931 (2013.01)

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Fig. 1

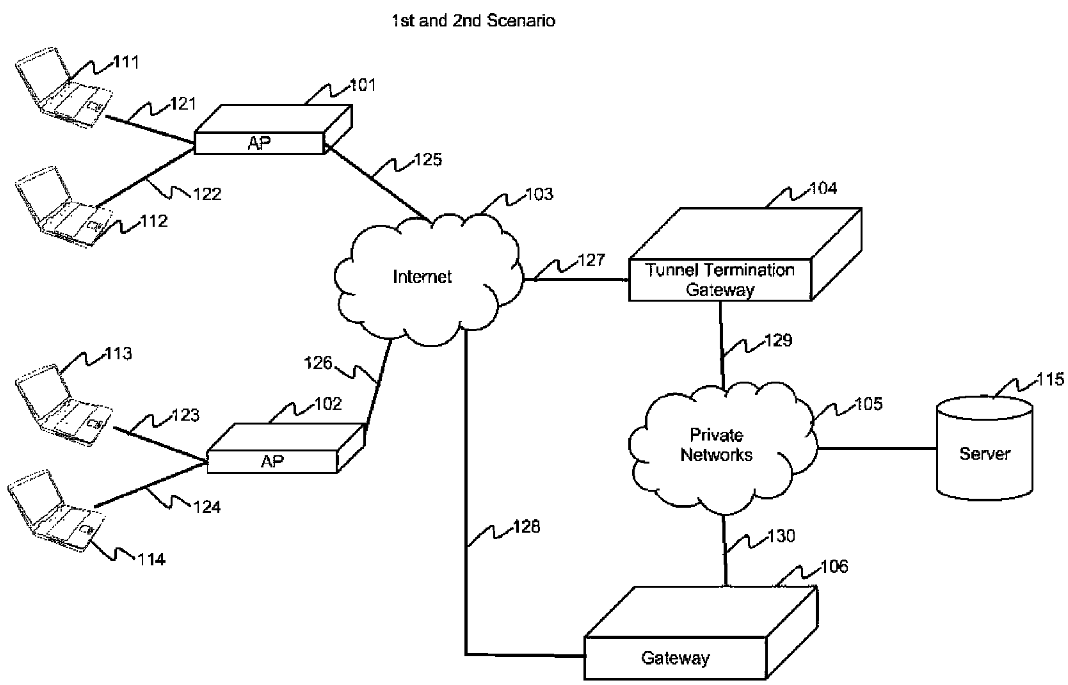

1st and 2nd Scenario
111
121
101
AP
125
122
112
103
104
Internet
127
Tunnel Termination
Gateway
113
126
129
115
123
102
105
Private
Networks
AP
Server
124
128
130
114
106
Gateway

Fig. 2

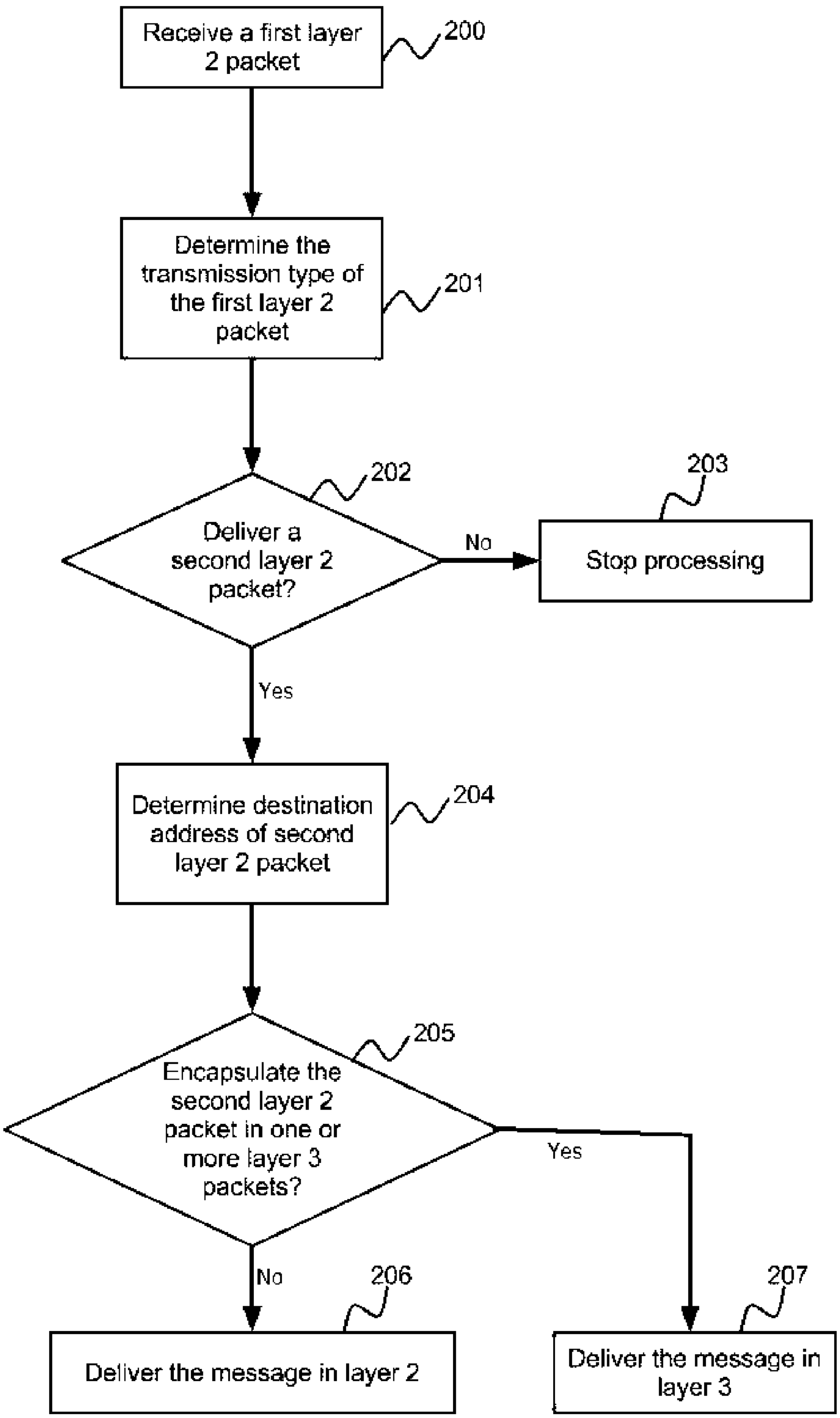

Receive a first layer 2 packet
200
Determine the transmission type of the first layer 2 packet
201
202
Deliver a second layer 2 packet?
No
203
Stop processing
Yes
Determine destination address of second layer 2 packet
204
205
Encapsulate the second layer 2 packet in one or more layer 3 packets?
Yes
No
206
207
Deliver the message in layer 2
Deliver the message in layer 3

Fig. 3A

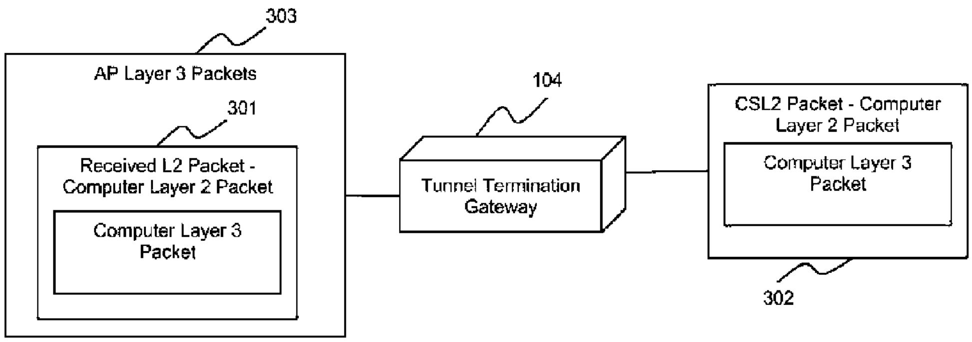


Fig. 3B

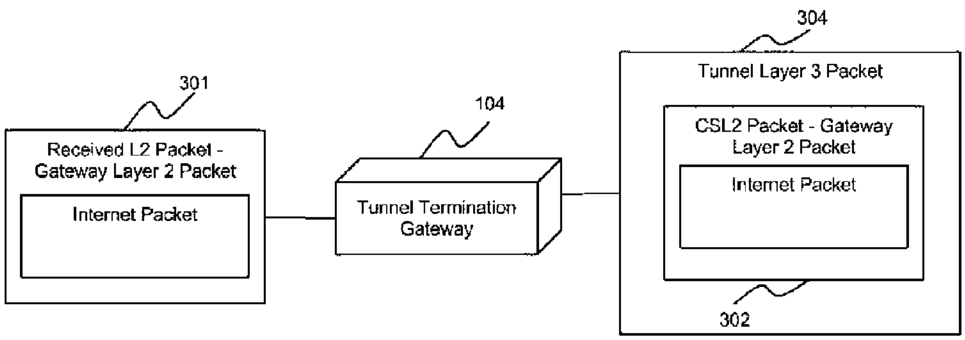


Fig. 3C

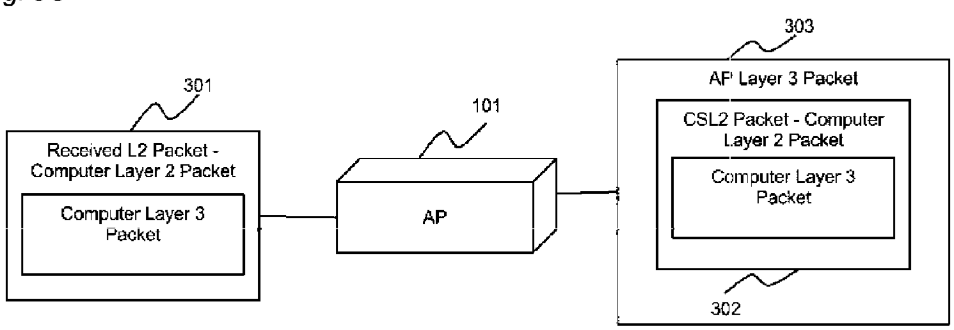


Fig. 3D

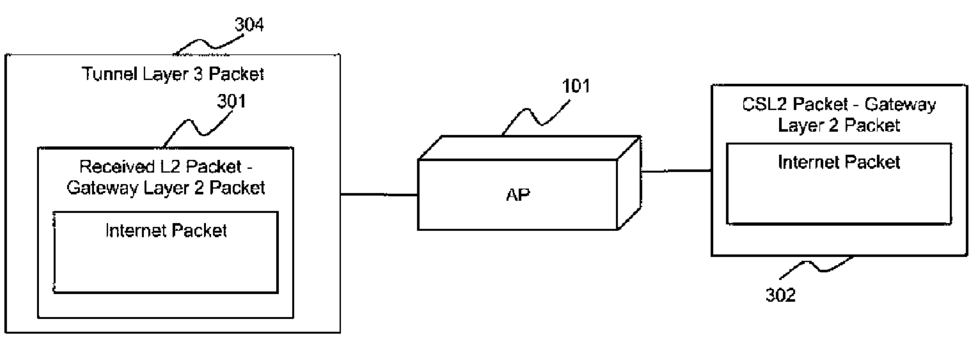
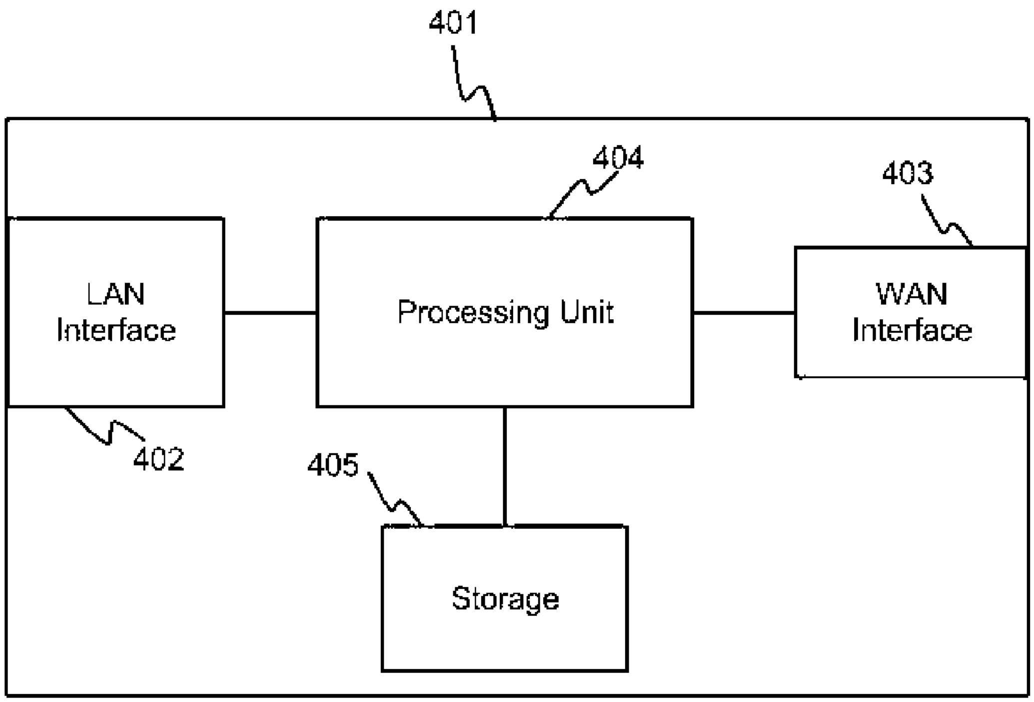


Fig. 4


401
404
403
LAN Interface
Processing Unit
WAN Interface
402
405
Storage

METHOD AND SYSTEM TO REDUCE WIRELESS NETWORK PACKETS FOR CENTRALISED LAYER TWO NETWORK

SUMMARY

A communication system capable of establishing and terminating at least one layer two tunnel, such as a VPN established by using Layer Two Tunnelling Protocol (L2TP), reduces broadcast or multicast packets by converting a first layer two packet from broadcast or multicast to a unicast layer two packet and convert a unicast layer two packet to a broadcast or multicast packet. The communication system determines whether to conduct the conversion according to the transmission type, origin of the first layer two packet or destination of the first layer two packet. According to one of the embodiments of the present invention, the communication system may determine not to send the broadcast or multicast layer two packet.

According to one of the embodiments of the present invention, the communication system learns the destination address of the unicast layer two packet by exchanging User Data Protocol (UDP) packets at a pre-defined port number. The communication system intercepts any UDP packets arriving at the specific UDP port and checks the payload of the UDP packets. If the payload matches a pre-defined format or content, the communication system is then able to recognize the layer two and layer three addresses of the sender of the UDP packet as the address for the layer two unicast destination address.

BACKGROUND ART

The use of wireless network communication systems that permit hosts to communicate via an optical cable, copper cable, or radio link has become widespread. Hosts are embedded with wireless communication electronics to communicate with other hosts and also to connect to a core network via access points, such as a local area network (LAN) and the Internet. The access point relays network packets between hosts and the core network, and also among hosts.

Hosts and base stations using Open Systems Interconnection (OSI) layer two technologies, such as Ethernet, to communicate with the core network and each other are less efficient at handling broadcast and multicast network packets. One kind of broadcast network packets on Internet Protocol (IP) networks belongs to Address Resolution Protocol (ARP) protocol network packets. For multicast network packets, the Internet Group Management Protocol (IGMP) is one of many communications protocol used by hosts and adjacent routers to establish multicast group memberships.

Due to historical technology development, hosts that belong to the same layer two networks are usually close together and share the same communication channel or the cost of communications with each other is low. Therefore, broadcast and multicast packets in layer two networks have not been a significant concern. When a layer two network is formed through layer three networks, broadcast and multicast packets in the layer two network may become a concern as the amount of packets increases. ARP proxy, proxy server, LAN segmentation, caching are common methods to reduce layer two broadcast and multicast packets.

When layer two packets are encapsulated in layer three packets, for example through Layer Two Tunnelling Protocol (L2TP) and virtual private network (VPN), the amount

of broadcast and multicast packets could have a severe negative impact on layer three network performance. Furthermore, when radio spectrum is used to transmit the layer three packets, there may not be enough capacity to transit the broadcast and multicast packets.

Prior arts ARP proxy, proxy server, LAN segmentation, caching and other broadcast and multicast packets reduction techniques do not allow transmission of broadcast and multicast packets selectively and particularly broadcast and multicast packets originated from a mobile network device through layer three networks.

U.S. Pat. No. 7,356,032 discloses a system and method for reducing broadcast packets among mobile units by using a cache to store Ethernet/IP address pairs in each base station. However, U.S. Pat. No. 7,356,032 cannot reduce broadcast packets if the mobile units are connecting to the core network using OSI layer two protocol through layer three networks. Also U.S. Pat. No. 7,356,032 relies on wireless access point to manage ARP packets. This also increases the complexity of the design of wireless access point.

FIG. **1** illustrates a network environment where communication systems and hosts, such as client computers **111**, **112**, **113** and **114**, communicate to wide area networks (WANs) or the Internet directly. In this particular network environment, those skilled in the art would appreciate that when client computer **111** sends OSI layer three packets to the Internet through the following steps: first, client computer **111** sends OSI layer three packets to wireless access point (AP) **101** (Computer Layer Two Packets) through radio link **121**, wherein the layer two packets encapsulate layer three packets from computer **111** (Computer Layer Three Packets); secondly, AP **101** communicates with Tunnel Termination Gateway **104** through interconnected networks, such as Internet **103**, by using layer three packets (AP Layer Three Packets) to encapsulate Computer Layer Two Packets; thirdly, Tunnel Termination Gateway **104** decapsulates AP Layer Three Packets to retrieve Computer Layer Two Packets and sends Computer Layer Two Packets to Internet Gateway **106** through private networks **105**; finally, Internet Gateway **106** decapsulates Computer Layer Two Packets to retrieve Computer Layer Three Packets and sends Computer Layer Three Packets to Internet **103**.

When there are OSI layer three packets for client computer **111** from Internet **103**: first, Internet Gateway **106** receives the layer three packets (Internet Packets) from Internet **103** and sends the Internet Packet to Tunnel Termination Gateway **104** by encapsulating Internet Packet in layer two packets (Gateway Layer Two Packets); secondly, Tunnel Termination Gateway **104** encapsulates Gateway Layer Two Packets in layer three packets (Tunneled Layer Three Packets) and sends Tunneled Layer Three Packets to AP **101** through Internet **103**; thirdly AP **101** decapsulates Tunnelled Layer Three Packets to retrieve Gateway Layer Two Packets and sends Gateway Layer Two Packets to client computer **111** through radio link **121**; finally client computer **111** retrieves Internet Packets by decapsulating Internet Packets from Gateway Layer Two Packets.

AP **101** and Tunnel Termination Gateway **104** are connected through a layer two tunnel by using layer three packets. The layer two tunnel may be implemented by using L2TP or other tunnelling protocols. Myriad other combinations and permutations of how to establish a layer two tunnel between two communication systems using layer three packets would be appreciated by those of ordinary skill given the present disclosure.

The steps of communicating with Internet **103** by client computer **112** are similar to the steps of communicating with Internet **103** by client computer **111**. The same steps are applied to computing devices **113** and **114**, however instead of using AP **101**, AP **102** is used. It is apparent to a skilled person in the art how the steps of communicating with Internet **103** also apply to hosts, client computers, computing devices and communication systems through wireless access points, Tunnel Termination Gateway **104**, private networks **105** and Internet Gateway **106**.

It may be noted that server **115** and client computers **111**, **112**, **113** and **114** all belong to the same layer two network as they are connected through layer three networks between AP **101** and Tunnel Termination Gateway **104** and between AP **102** and Tunnel Termination Gateway **104**. Therefore, when server **115** sends a layer two broadcast or multicast packet, the broadcast or multicast packet is then duplicated by Tunnel Termination Gateway **104**, AP **101** and AP **102** and sent to client computers **111**, **112**, **113** and **114**. This type of broadcast or multicast network packets may easily consume a significant part of network resources between AP **101** and Internet **103**, between AP **102** and Internet **103**, between Tunnel Termination Gateway **104** and Internet **103**, radio spectrum of AP **101** and radio spectrum AP **102**. This invention aims to reduce broadcast and multicast network packets in the network environment just described.

DISCLOSURE OF INVENTION

The ensuing description provides preferred exemplary embodiment(s) only, and is not intended to limit the scope, applicability or configuration of the invention. Rather, the ensuing description of the preferred exemplary embodiment(s) will provide those skilled in the art with an enabling description for implementing a preferred exemplary embodiment of the invention. It is understood that various changes may be made in the function and arrangement of elements without departing from the spirit and scope of the invention as set forth in the appended claims.

Specific details are given in the following description to provide a thorough understanding of the embodiments. However, it will be understood by one of ordinary skill in the art that the embodiments may be practiced without these specific details. For example, circuits may be shown in block diagrams in order not to obscure the embodiments in unnecessary detail. In other instances, well-known circuits, processes, algorithms, structures, and techniques may be shown without unnecessary detail in order to avoid obscuring the embodiments.

Also, it is noted that the embodiments may be described as a process which is depicted as a flowchart, a flow diagram, a data flow diagram, a structure diagram, or a block diagram. Although a flowchart may describe the operations as a sequential process, many of the operations may be performed in parallel or concurrently. In addition, the order of the operations may be re-arranged. A process is terminated when its operations are completed, but could have additional steps not included in the figure. A process may refer to a method, a function, a procedure, a subroutine, a subprogram, etc. When a process corresponds to a function, its termination corresponds to a return of the function to the calling function or the main function.

Moreover, as disclosed herein, the term "computer storage medium" may represent one or more devices for storing data, including read only memory (ROM), random access memory (RAM), magnetic RAM, core memory, magnetic disk storage mediums, optical storage mediums, flash memory devices and/or other machine readable mediums for storing information. The term "machine-readable medium" includes, but is not limited to portable or fixed storage devices, optical storage devices, wireless channels and various other mediums capable of storing, containing or carrying instruction(s) and/or data.

Furthermore, embodiments may be implemented by hardware, software, firmware, middleware, microcode, hardware description languages, or any combination thereof. When implemented in software, firmware, middleware or microcode, the program code or code segments to perform the necessary tasks may be stored in a machine readable medium such as computer storage medium. A processing unit(s) may perform the necessary tasks. A code segment may represent a procedure, a function, a subprogram, a program, a routine, a subroutine, a module, a software package, a class, or any combination of instructions, data structures, or program statements. A code segment may be coupled to another code segment or a hardware circuit by passing and/or receiving information, data, arguments, parameters, or memory contents. Information, arguments, parameters, data, etc. may be passed, forwarded, or transmitted via any suitable means including memory sharing, message passing, token passing, network transmission, etc.

A network interface, such as LAN interface and WAN interface, that may be provided by the communication system (CS) is an Ethernet interface, a frame relay interface, an antenna interface, a fibre optic interface, a cable interface, a DSL interface, a token ring interface, a serial bus interface, an universal serial bus (USB) interface, Firewire interface, Peripheral Component Interconnect (PCI) interface, etc. In one variant, a network interface is in a processing unit and therefore the agent for connecting with optical fiber, cables or antenna may directly connect with the processing unit. In one variant, a network interface may connect to a Wi-Fi adapter for Wi-Fi network connection. In one variant, a network interface may connect to a USB port and the USB port may connect to an external modem for wireless WAN connection, such as a USB 3G modem, USB LTE modem, USB WiMAX Modem, USB Wi-Fi Modem, or other modem for wireless communications. Myriad other combinations and permutations of the foregoing will be appreciated by those of ordinary skill given the present disclosure.

In order to improve readability, Open Systems Interconnection (OSI) layer two is interchangeable in this present invention with layer two and similarly OSI layer three is interchangeable with layer two.

A base station, interchangeable in this present invention with access point, is a radio receiver/transmitter that serves as the hub of the local wireless network, and may also be the gateway between a wired network and the wireless network. It may consist of a transmitter and wireless router.

A host is an electronic device, such as a mobile phone, computer, server, router, switch, sensor and etc, connected to a computer network. A host may offer information resources, services, and applications to users or other nodes on the network. A host is a network node that is assigned a network layer host address. Hosts may have one or more Internet Protocol (IP) addresses assigned to their network interfaces. The addresses are configured either manually by an administrator, automatically at start-up by means of the Dynamic Host Configuration Protocol (DHCP), or by stateless address auto-configuration methods.

A pre-defined layer two broadcast destination address is an address known to the CS as a broadcast address, including Ethernet broadcast address FF:FF:FF:FF:FF:FF in hexadecimal, an address used by CS manufacturer for proprietary broadcasting and an address configured by the administrator of the CS manufacturer for proprietary broadcasting. A multicast destination address is an address known to the CS as a multicast address, including multicast address learnt by the CS through IGMP.

A CS is a host capable of establishing and terminating at least one layer two tunnel, such as a VPN established by using L2TP, receiving layer two packets, and sending layer two packets. As the CS has to be able to establish and terminate at least one layer two tunnel, the CS has to able to receive and send layer three packets. The CS may communicate to other hosts through wireless and/or wired networks. The CS may be an 802.11 access point capable of handling IEEE 802.11 protocol. The CS may be an Internet Protocol (IP) router. The CS may be an IP router with Ethernet switch capability. The CS may be a host capable of communicating with other hosts using one or more OSI layer two protocols, such as Ethernet, High-Speed Packet Access (HSPA), HSPA+, Long Term Evolution (LTE), WiMax, GPRS, EDGE, GSM, CDMA, WiFi, CDMA2000, WCDMA, TD-SCDMA, BLUETOOTH, and WiBRO.

FIG. **2** is a flow chart illustrating how communication system reduces broadcast and multicast packets according to one of the embodiments of the present invention. When a communication system (CS) receives a layer two packet (Received L2 Packet) at step **200** through a network connection, which may be implemented by different network connection technologies, including wireless, wire and optical fiber, the CS determines whether transmission type of the Received L2 Packet is broadcast, multicast or unicast at step **201**. According to one of the embodiments of present invention, the CS determines the transmission type by checking the destination address of the Received L2 Packet. In Ethernet network, media access control address (MAC address) the multicast and broadcast addresses are FF:FF:FF:FF:FF:FF in hexadecimal. As it is possible that the Received L2 Packet is encapsulated in one or more layer three packets (Received L3 Packets), the CS may need to decapsulate the Received L3 Packet to retrieve Received L2 Packet at step **201**. Hosts communicating with each other using IP may use IGMP to determine the multicast address.

CS determines whether to send another layer two packet (CSL2 Packet) at step **202**. According to one of the embodiments of present invention, CS sends CSL2 Packet if transmission type of Received L2 Packet is unicast. According to one of the embodiments of present invention, CS does not send CSL2 Packet if transmission type of Received L2 Packet is broadcast or multicast. According to one of the embodiments of present invention, CS sends a broadcast or multicast CSL2 Packet if transmission type of Received L2 Packet is unicast and the destination address of the Received L2 Packet is a pre-determined address. According to one of the embodiments of present invention, CS sends a broadcast CSL2 Packet if transmission type of Received L2 Packet is unicast and the Received L3 Packets is received at a pre-defined port. According to one of the embodiments of present invention, the decision whether to send CSL2 Packet is based on one or more pre-defined rules (Pre-defined Rules).

CSL2 Packet is based on the Received L2 Packet. The content carried by the CSL2 Packet is from the content carried by the Received L2 Packet.

The destination address of CSL2 Packet is determined at step **204**. According to one of the embodiments of present invention, when the transmission type of CSL2 Packet is broadcast, the destination address is a broadcast address, such as FF:FF:FF:FF:FF:FF used in Ethernet. When the transmission type of CSL2 Packet is unicast, the destination address is the layer two address of the receiver of CSL2 packet, such as a Media Access Control (MAC) address of the receiver of CSL2 Packet in Ethernet protocol. According to one of the embodiments of present invention, the destination address is determined according to Pre-defined Rules.

The number of combinations of the pre-defined rules may be numerous. Network administrators and/or communication system manufacturers may configure the pre-defined rules according to their needs and network environments.

Pre-defined Rules may be inputted to the CS manually by the CS administrator, retrieved from a server either locally or remotely or pre-determined by the manufacturer of the CS. The Pre-defined Rules are stored in a machine-readable medium which may be implemented in the CS or another device.

Scenarios

The implementations consider at least the next eight scenarios. The first four scenarios are associated with the CS implementing the present invention being Tunnel Termination Gateway **104** which is connected to private networks **105** and Internet **103**. Tunnel Termination Gateway **104** may be implemented by using a router, a server, a switch or any communication system that is capable of terminating layer two tunnel. Tunnel Termination Gateway **104** decides whether to send CSL2 Packet and determines the destination address according to the following four scenarios and may be implemented in Pre-defined Rules.

The second four scenarios are associated with the CS implementing the present invention being an AP, such as AP **101** and AP **102**, and connected to hosts such as computing devices **111**, **112**, **113** and **114** and Internet **103**. AP **101** and AP **102** may also be implemented by using a router, a server, a switch or any communication system that is capable of communicating wirelessly and terminating layer two tunnel. AP **101** or AP **102** decides whether to send CSL2 Packet and determines the destination address according to the next four scenarios and may be implemented according to a set of Pre-defined Rules.

The first scenario is that the Received L2 Packet is received by Tunnel Termination Gateway **104** through Internet **103** with a pre-defined layer two broadcast destination address or a multicast destination address. According to one of the embodiments of present invention, as the destination address of Received L2 Packet is a pre-defined broadcast or multicast destination address; Tunnel Termination Gateway **104** determines whether the Received L2 Packet is intended for broadcast or multicast to private networks **105**. Therefore, Tunnel Termination Gateway **104** decides that a CSL2 Packet is to be sent with broadcast transmission type or multicast transmission type to the private network at step **202** and the destination address is a broadcast or multicast layer two address at step **204**. The pre-defined layer two broadcast destination or multicast address of the Received L2 Packet may be any layer two address, such as FF:FF:FF:FF:FF:FF for Ethernet, as long as Tunnel Termination Gateway **104** is able to recognize the use of the specific layer two address is for broadcast or multicast purpose. When the Received L2 Packet is originated from one of the computing devices **111**-**114**, the Received L2 Packet is the same as the Computer Layer Two Packet mentioned earlier.

FIG. **3**A illustrates the relationship among level 2 and level 3 packets received and sent by Tunnel Termination Gateway **104** when the Received L2 Packet **301** is sent by an AP and received by Tunnel Terminal Gateway **104**. Here, the Received L2 Packet **301** is a Computer Layer Two Packet, which encapsulates Computer Layer Three Packet and is encapsulated in AP Layer Three Packets **303**. Computer Layer Three Packet is the layer three packet sent by a computing device, one of computing devices **111-114**. Tunnel Termination Gateway **104** decapsulates AP Layer Three Packets **303** to retrieve Computer Layer Two Packet, which now becomes CSL2 Packet because Tunnel Termination Gateway **104** sends CSL2 Packet **302** to Private Networks **104**. Computer Layer Three Packet remains encapsulated in the CSL2 Packet.

According to one of the embodiments of present invention, when the pre-defined layer two broadcast or multicast destination address is the layer two address of Tunnel Termination Gateway **104**, Tunnel Terminal Gateway **104** checks the port number of the Computer Layer Three Packet, which is encapsulated in the Received L2 Packet, to determine whether the Received L2 Packet is for broadcast or multicast purpose.

The second scenario is that the Received L2 Packet is received by Tunnel Termination Gateway **104** through Internet **103** with a non-pre-defined layer two broadcast or multicast destination address. According to one of the embodiments of present invention, as the destination address of Received L2 Packet is not a pre-defined broadcast or multicast destination address, Tunnel Termination Gateway **104** may determine that the Received L2 Packet is intended for unicast to a specific layer two address in the private networks **105**. Therefore, Tunnel Termination Gateway **104** decides that a CSL2 Packet is to be sent with unicast transmission type to a device, such as Gateway **106** and Server **115**, through private network at step **202** and the destination address is a unicast layer two address at step **204**. When the Received L2 Packet is originated from one of the computing devices **111-114**, the Received L2 Packet is the same as the Computer Layer Two Packets mentioned earlier.

It should be noted when Tunnel Termination Gateway **104** receives the Received L2 Packet through Internet **103**, the Received L2 Packet is encapsulated in AP Layer Three Packets. Tunnel Termination Gateway **104** may decapsulate the AP Layer Three Packets to retrieve the Received L2 Packet. According to one of the embodiments of present invention, the decapsulation process is conducted by another communication system that terminates the layer two tunnels established with AP **101** and AP **102**. In such case, the Received L2 Packet is received from that communication system.

Regardless of the transmission type of CSL2 Packet, when Tunnel Termination Gateway **104** sends CSL2 Packet through private networks **105**, Tunnel Termination Gateway **104** need not encapsulate CSL2 Packet in one or more layer three packets at step **205** because private network **105** is a layer two network. Therefore, step **206** is then executed, instead of step **207**.

The third scenario is that the Received L2 Packet is received by Tunnel Termination Gateway **104** through private network **105** with a pre-defined layer two broadcast or multicast destination address. According to one of the embodiments of present invention, as the destination address of Received L2 Packet is a pre-defined broadcast or multicast destination address, Tunnel Termination Gateway **104** may determine that the Received L2 Packet is intended for broadcasting or multicasting to AP **101-102** and computing devices **111-114** through Internet **103**. Therefore, Tunnel Termination Gateway **104** decides that no CSL2 Packet is sent at step **202** in order to reduce network packets and/or conserve wireless spectrum. The operation stops at step **203**.

FIG. **3**B illustrates the relationship among level 2 and level 3 packets received and sent by Tunnel Termination Gateway **104** when the Received L2 Packet **301** is received through Private Networks **104**. Received L2 Packet **301** received by Tunnel Terminal Gateway **104** is a Gateway Layer Two Packet, which encapsulates Internet Packet. Internet Packet is a layer three packet received by Gateway **106** and intended to be sent to one of or all computing devices **111-114**. CSL2 Packet **302** is encapsulated in Tunnel Layer Three Packet **304** and same as Gateway Layer Two Packet. Tunnel Termination Gateway **104** sends Tunnel Layer Three Packet **304** to one of the AP if the transmission type is unicast or to all AP if the transmission type is broadcast or multicast.

The fourth scenario is that the Received L2 Packet is received through private network **105** with a non-pre-defined layer two broadcast or multicast destination. According to one of the embodiments of present invention, as the destination address of Received L2 Packet is not a pre-defined layer two broadcast or multicast destination, Tunnel Termination Gateway **104** determines that the Received L2 Packet is intended for unicast to a specific layer two address belonging to one of computing devices **111-114** reachable through Internet **103**. Therefore, Tunnel Termination Gateway decides that a CSL2 Packet is to be sent with unicast transmission type through Internet **103** at step **202** and the destination address is a specific layer two address at step **204** of one of computing devices **111-114** and AP **101-102**. The CSL2 Packet is determined to be encapsulated in one or more layer three packets at step **205** and the one or more layer three packets, which are the same as Tunnelled Layer Three Packets, are sent at step **207**.

It should be noted that when the Received L2 Packet is received from Gateway **104**, Received L2 Packet may have already encapsulated Internet Packets. In such case, Received L2 Packet is the same as Gateway Layer Two Packet and Tunnelled Layer Three Packet encapsulates CSL2 Packet.

The fifth scenario is that the Received L2 Packet is received by AP **101** from a directly connected host, such as computing device **113**, with a pre-defined layer two broadcast or multicast destination address. According to one of the embodiments of present invention, as the destination address of Received L2 Packet is a pre-defined broadcast or multicast destination address, AP **101** is able to determine that the Received L2 Packet is intended for broadcast or multicast respectively. Therefore, it is decided that a CSL2 Packet is sent to Tunnel Termination Gateway **104** with broadcast or multicast transmission type at step **202** and the destination address may be a broadcast layer two address or the layer two address of Tunnel Termination Gateway **104** at step **204**. As the Tunnel Termination Gateway **104** is only reachable through Internet **103**, AP **102** has to send the CSL2 Packet through Internet **103**. AP **102** at step **205** and step **207** encapsulates and sends the CSL2 Packet in one or more layer three packets, which are AP Layer Three Packet, to Tunnel Termination Gateway **104** through Internet **103** using the layer three address of Tunnel Termination Gateway **104**.

FIG. **3**C illustrates the relationship among level 2 and level 3 packets received and sent by an AP when the Received L2 Packet **301** is received from one of the computing devices **111-114**. Received L2 Packet **301** received by the AP is a Computer Layer Three Packet. The AP retrieves the Computer Layer Three Packet from Received L2 Packet **301** and encapsulates the Computer Layer Three Packet in CSL2 Packet **302**, which is encapsulated in AP Layer Three Packet **303**. The AP then sends AP Layer Three Packet **303** to Tunnel Termination Gateway **104**.

The port number of AP Layer Three Packet may be set to a pre-defined port number to inform Tunnel Termination Gateway **104** that the AP Layer Three Packet encapsulates a CSL2 Packet intended for broadcasting. Depending on the preferences of the manufacturer and/or the administrator of AP **101**, AP **101** may or may not broadcast the Received L2 Packet to other hosts directly connected. If AP **101** does not broadcast the CSL2 Packet to other hosts directly connected, network packets may be reduced. If AP **101** decides to broadcast the CSL2 Packet to other hosts directly connected at step **205**, the CSL2 Packet is then sent to the hosts at step **207**.

The sixth scenario is that the Received L2 Packet is received by AP **101** from a directly connected host, such as computing device **111**, with a non-pre-defined layer two broadcast or multicast destination address. According to one of the embodiments of present invention, as the destination address of Received L2 Packet is not a pre-defined broadcast destination address, AP **101** may determine that the Received L2 Packet is intended for unicast to a specific layer two address, which may belong to another device directly connecting to AP **101**, such as computing device **112** or another device in the same layer two network reachable through Internet **103**. Therefore, AP **101** decides that a CSL2 Packet is to be sent at step **202** and also decides that the transmission type is unicast at step **204**. The layer two destination address of the CSL2 Packet is the destination address of the Received L2 Packet. If AP **101** may send the destination address of the CSL2 Packet without passing through Internet **103**, such as computing device **112**, AP **101** may send the CSL2 Packet to computing device **112** with layer three encapsulation. If AP **101** has to send the CSL2 Packet through Internet **103**, AP **101** at step **205** and step **207** encapsulates and sends the CSL2 Packet in one or more layer three packets, which are AP Layer Three Packets, to Tunnel Termination Gateway **104** through Internet **103** using the layer three address of Tunnel Termination Gateway **104**.

The seventh scenario is that the Received L2 Packet is received by AP **101** through Internet **103** with a pre-defined layer two broadcast destination address. Using FIG. **1** for illustrative purpose, when the destination address of Received L2 Packet is a pre-defined broadcast destination address, the Received L2 Packet is intended for broadcasting to computing devices **111** and **112**. Depending on the preferences of the manufacturer and/or the administrator of AP **101**, AP **101** may or may not broadcast the Received L2 Packet to other computing devices **111** and **112** at step **202**. If AP **101** does not broadcast the CSL2 Packet to hosts directly connected, network packets may be reduced and the process stops at step **203**. If AP **101** decides to broadcast the CSL2 Packet to other hosts directly connected at step **202**, the destination address of CSL2 Packet is the pre-defined layer two broadcast destination, such as MAC Address FF:FF:FF:FF:FF:FF in Ethernet at step **204**. As computing devices **111** and **112** are in the same layer two network, there is no layer three encapsulation at step **205** and the CSL2 Packet is sent at step **206**.

FIG. **3**D illustrates the relationship among level 2 and level 3 packets received and sent by an AP when the Received L2 Packet **301** is sent by Tunnel Termination Gateway **104** and received by one of AP **101** or **102**. Here, the Received L2 Packet **301** is a Gateway Layer Two Packet, which encapsulates Internet Packet and is encapsulated in Tunnel Layer Three Packets **304**. The AP decapsulates Tunnel Layer Three Packet **304** to retrieve Gateway Layer Two Packet. Using FIG. **1** for illustrative purpose, the AP sends CSL2 Packet **302**, which is the Gateway Layer Two Packet, to one of the computing devices **111**-**114** if the transmission type is unicast or to all computing devices **111**-**114** if the transmission type is broadcast.

The eighth scenario is that the Received L2 Packet is received by AP **101** through Internet **103** with a non-pre-defined layer two broadcast destination address. According to one of the embodiments of present invention, as the destination address of Received L2 Packet is not a pre-defined broadcast destination address, the Received L2 Packet is intended for unicast to a specific computing device directly connected, such as one of computing devices **111** and **112**. Therefore, AP **101** decides that a CSL2 Packet is to be sent at step **202** and also decides that the transmission type is unicast at step **204**. The layer two destination address of the CSL2 Packet is the destination address of the Received L2 Packet. AP **101** sends the CSL2 Packet to either computing device **111** or **112** at step **206** without layer three encapsulation at step **205**. As the Received L2 Packet is received through Internet **103**, it is encapsulated in one or more layer three packets, which are Tunnel Layer Three Packets originated from Tunnel Termination Gateway **104**. AP **101** has to decapsulate Tunnel Layer Three Packets in order to retrieve the Received L2 Packet.

It should be noted that the payload contained in Received L2 Packet should be the same as the payload contained in CSL2 Packet but the layer two destination address of Received L2 Packet may be different from of CSL2 Packet. This is because the CS, which may be an AP or Tunnel Termination Gateway, may change the layer two destination address in order to convert a layer two broadcast or multicast destination address to a layer two unicast destination address.

According to one of the embodiments of present invention, instead of relying on the layer two destination address of the Received L2 Packet or relying on port number of the layer three packets encapsulating the Received L2 Packet to determine whether the Received L2 Packet is intended for broadcast or multicast, the CS examines the information stored in the payload of the Received L2 Packet in order to make the decision.

According to one of the embodiments of present invention, the Received L2 Packet encapsulates an IP Address Resolution Protocol (ARP) packet, which may be a probe, announcement or reply packet. If the ARP packet is a probe or announcement packet, the transmission type of the Received L2 Packet is broadcast or multicast. Then depending on the origin of the Received L2 Packet, such as from private networks **105** or from one of the computing devices **111**-**114**, the CS, such as AP **101**, AP **102** or Tunnel Termination Gateway **104** may determine whether to broadcast or multicast a corresponding CSL2 Packet. It is apparent to a skilled person in the art how to recognize if the Received L2 Packet encapsulates an IP ARP packet and the type of ARP packet.

According to one of the embodiments of present invention, when Received L2 Packet is an ARP reply packet, the CS, such as AP **101**, AP **102** or Tunnel Termination Gateway **104**, caches the IP address and MAC address pair of the ARP reply packet. The transmission type of the Received L2 Packet may be unicast or broadcast. When the CS receives another Received L2 Packet, which may be unicast, broadcast or multicast, containing an ARP probe packet later, CS then responds to the sender of the ARP probe packet by sending a CSL2 Packet with the cached IP address and MAC address pair. Therefore, the CS is acting like an ARP cache. It is apparent to a skilled person in the art how to implement an ARP cache. A computer storage medium may be used as a cache for storing the cached IP address and MAC address pair.

According to one of the embodiments of present invention, the Received L2 Packet encapsulates an IP Dynamic Host Configuration Protocol (DHCP) packet, which may be a discovery, offer, request, acknowledgement, information or releasing packet. If the DHCP packet is a discovery or request packet, the transmission type of the packet is broadcast. Then, depending on the origin of the Received L2 Packet, such as from private networks **105** or from one of the computing devices **111-114**, the CS, such as Tunnel Termination Gateway **104**. AP **101** or AP **102**, then determines whether to broadcast or multicast a corresponding CSL2 Packet. It is apparent to a skilled person in the art how to recognize if the Received L2 Packet encapsulates an IP DHCP packet and the type of DHCP packet.

According to one of the embodiments of present invention, when transmission type of Received L2 Packet is broadcast or multicast and transmission type of CSL2 Packet is unicast, the layer two destination address in the case of Ethernet is changed from broadcast address FF:FF:FF:FF:FF:FF or a multicast address to a layer two unicast address. However, if the CS is an AP, such as one of AP **101-102**, the AP needs to learn the layer two destination address, which is the layer two address of Tunnel Termination Gateway **104**. The layer two address of Tunnel Termination Gateway **104** may be inputted by network administrator, received by querying another communication system whose address is pre-configured, or by learnt from the response after sending a pre-defined layer three packet. If a pre-defined layer three packet is used, AP may then learn the destination address from the reply of the pre-defined layer three packet.

According to one of the embodiments of present invention, layer three packets exchanged between Tunnel Termination Gateway **104** and APs are used to determine the destination address of CSL2 Packet when the transmission type of Received L2 Packet is broadcast or multicast. An AP and Tunnel Termination Gateway **104** both listen to the same specific User Data Protocol (UDP) port. The AP first sends a UDP packet to the specific UDP port of the Tunnel Termination Gateway **104**, whose IP address is learnt by the AP from DHCP packets or pre-determined configuration. Tunnel Termination Gateway **104** intercepts any UDP packets arriving at the specific UDP port and checks the payload of the UDP packets. If the payload matches a pre-defined format or content, Tunnel Termination Gateway **104** is then able to recognize the layer two address of the AP, and may send a second UDP packet to the same specific UDP port of AP for confirmation. When AP received the second UDP packet, it also verifies whether the payload of the second UDP packet matches a pre-defined format or content and, if so, the AP stores the layer two source address of the second UDP packet, such as the MAC address of the second UDP packet. From then on, until further reset or change of network conditions, AP sets the destination address of CSL2 packet to the layer two source address of the second UDP packet when the transmission type of Received L2 Packet is broadcast or multicast.

According to one of the embodiments of present invention, the communication system, such as AP **101**, AP **102** and Tunnel Termination Gateway **104** may be composed of two communication systems. The first communication system is responsible for establishing layer two tunnels by using layer three communication technologies, such as a L2TP network server. The second communication system is responsible for determine whether to send CSL2 packet, the transmission type of the CSL2 packets and the destination address of CSL2 packets.

Communication System

FIG. **4** illustrates one of the embodiments of present invention of a communication system according to the present invention described. The communication system **401** comprises a processor unit(s) **402**, a data storage **405**, at least one LAN interface **402**, and at least one WAN interface **403**, for use with other network apparatus such as WiMAX routers, Ethernet switches, IP routers and other packet network devices, network management and provisioning systems, local PCs, etc. Processor unit(s) **402** couples to data storage **405**, LAN interface **402**, and WAN interface **403** respectively. Other components which may be utilized within the network device **401** include amplifiers, board level electronic components, as well as media processors and other specialized SoC or ASIC devices. Support for various processing layers and protocols (e.g., 802.3, DOCSIS MAC, DHCP, SNMP, H.323/RTP/RTCP, VoIP, SIP, etc.) may also be provided as required.

Communication system **401** may take any number of physical forms, comprising for example one of a plurality of discrete modules or cards within a larger network edge or hub device of the type well known in the art and may also comprise firmware, either alone or in combination with other hardware/software components. Alternatively, Communication system **401** may be a stand-alone device or module disposed at other computing device or network device, and may even include its own RF front end (e.g., modulators, encryptors, etc.) or optical interface so as to interface directly with other computing devices and network devices. Numerous other configurations may be used. Communication system **401** may also be integrated with other types of components (such as mobile base stations, satellite transceivers, video set-top box, encoders/decoders, etc.) and form factors if desired.

Processing unit **404** may be implemented by using one or more central processing units, network processors, microprocessors, micro-controllers, FPGAs, ASICs or any device capable of performing instructions to perform the basic arithmetical, logical, and input/output operations of the system.

Computer storage medium **405** may be implemented by using at least one DRAM, SDRAM, Flash RAM, optical memory, magnetic memory, hard disk, and/or any computer readable media that are able to provide data storage capability. Computer storage medium **405** may be used to provide instructions to processing units **402** and to provide data storage to store cache, identifiers, conditions, thresholds, network performance statistics, web pages, messages and other data to facilitate the operation of the communication system **401**.

When communication system **401** receives a Received L2 Packet through a network connection in either LAN interface **402** or WAN interface **403**, processing unit **404** determines whether transmission type of the Received L2 Packet is broadcast, multicast or unicast. The network connection may be implemented by different network connection technologies, including wireless, wire and optical fiber. According to one of the embodiments of present invention, the processing unit **404** determines the transmission type by checking the destination address of the Received L2 Packet. As it is possible that the Received L2 Packet is encapsulated in one or more Received L3 Packets, processing unit **404** may need to decapsulate the Received L3 Packet to retrieve

Received L2 Packet. Hosts communicating by using IP may use IGMP to determine the multicast address.

Processing unit **404** determines whether to send a CSL2 Packet. If processing unit **404** determines to send a CSL2 packet, the CSL2 packet is sent through WAN interface **403** if the Received L2 Packet is received from LAN interface **402**. On the other hand, if processing unit **404** determines to send a CSL2 packet, the CSL2 packet is sent through LAN interface **402** if the Received L2 Packet is received from WAN interface **403**. CSL2 According to one of the embodiments of present invention, processing unit **404** decides to send CSL2 Packet if transmission type of Received L2 Packet is unicast. According to one of the embodiments of present invention, processing unit **404** decides not to send CSL2 Packet if transmission type of Received L2 Packet is broadcast or multicast. According to one of the embodiments of present invention, processing unit **404** decides to send a broadcast or multicast CSL2 Packet if transmission type of Received L2 Packet is unicast and the destination address of the Received L2 Packet is a pre-determined address. According to one of the embodiments of present invention, processing unit **404** decides to send a broadcast CSL2 Packet if transmission type of Received L2 Packet is unicast and the Received L3 Packets is received at a pre-defined port. According to one of the embodiments of present invention, the decision whether to send CSL2 Packet is based on one or more Pre-defined Rules.

Computer storage medium **405** may be used to store the content carried by Received L2 Packet. In one variant, once the corresponding CSL2 Packet is sent, the content carried by the Received L2 packet that is stored in computer storage medium **405** is then removed in order to release data storage space.

The destination address of CSL2 Packet is determined by processing unit **404**. According to one of the embodiments of present invention, the destination address is determined by process unit **404** according to Pre-defined Rules. The Pre-defined Rules are stored in computer storage medium **405**.

Referring to the eight scenarios described earlier, processing unit **404** of a communication system, such as Tunnel Termination Gateway **104**, AP **101** and AP **102** performs the function of determining whether a Received L2 Packet is intended for broadcast, multicast or unicast, determining the transmission type of a CSL2 Packet, the destination address of the CSL2 Packet, establishing VPN, terminating VPN, encapsulating a layer two packets in at least one layer three packet, decapsulating a layer two packet from at least one layer three packet, and other processing functions.

According to one of the embodiments of present invention, the communication system, such as AP **101**, AP **102** and Tunnel Termination Gateway **104** may be composed of at least one layer three router and at least one layer two switch. The at least one layer three router is responsible for establishing layer two tunnels by using layer three communication technologies, such as a L2TP network server. The at least one layer two switch is responsible for determining whether to send CSL2 packet, the transmission type of the CSL2 packets and the destination address of CSL2 packets. Each of the layer three router and layer two switch has its own processing unit, computer storage medium, LAN interface, WAN interface to carry out the functions of communication system **401**. The at least one layer three router is used to connect to an external network, such as interconnected network or the Internet. The LAN interface of the at least one layer three router is connected to one of the ports of the at least one layer two switch. Another one of the ports of the at least one layer two switch is connected to the private network. It is apparent to a skilled person in the art how to implement at least one layer three router and at least one layer two switch for carrying out the functions of communication system **401**.

According to one of the embodiments of present invention, at least one LAN interface of communication system **401** is an 802.11 interface that allows hosts to connect to the communications system using IEEE 802.11 protocol, including 802.11a, 802.11b, 802.11g, 802.11n, 802.11ac, and 802.11ad; at least one WAN interface is an 802.16 interface that allows communication system **401** to connect to inter-network or the Internet through IEEE 802.16 protocol. In one variant, the WiMAX modem is embedded inside communication system **401** and therefore WAN interface may directly connect with an antenna. In one variant, an IEEE 802.11 modem is embedded inside communication system **401** and therefore LAN interface may directly connect with at least one antenna. In one variant, the an IEEE 802.16 modem is embedded inside communication system **401** and therefore WAN interface may directly connect with at least one antenna.

Brief Description Of Drawings

FIG. **1** illustrates a network environment where communication systems and hosts, such as client computers **111**, **112**, **113** and **114** communicate to wide area networks (WANs) or the Internet directly.

FIG. **2** is a flow chart illustrating how communication system reduces broadcast and multicast packets according to one of the embodiments of the present invention.

FIG. **3**A illustrates the relationship among level 2 and level 3 packets received and sent by Tunnel Termination Gateway **104** when the Received L2 Packet **301** is sent by an AP and received by Tunnel Terminal Gateway **104**.

FIG. **3**B illustrates the relationship among level 2 and level 3 packets received and sent by Tunnel Termination Gateway **104** when the Received L2 Packet **301** is received through Private Networks **104**.

FIG. **3**C illustrates the relationship among level 2 and level 3 packets received and sent by an AP when the Received L2 Packet **301** is received from one of the computing devices **111-114**.

FIG. **3**D illustrates the relationship among level 2 and level 3 packets received and sent by an AP when the Received L2 Packet **301** is sent by Tunnel Termination Gateway **104** and received by one of AP **101** or **102**.

FIG. **4** illustrates one of the embodiments of present invention of a communication system according to the present invention described.

The invention claimed is:

1. A method of operating a first communication system, comprising the steps of:

receiving a first Open Systems Interconnection (OSI) layer two packet from a first network interface;

determining whether transmission type of the first OSI layer two packet is unicast, broadcast, or multicast transmission;

determining whether destination address of the first OSI layer two packet is a predefined broadcast or multicast address;

if the destination address of the first OSI layer two packet is a first predefined broadcast or multicast address, sending a second OSI layer two packet to the first predefined broadcast or multicast address according to predefined rules corresponding to the predefined broadcast or multicast address;

sending the second OSI layer two packet to the destination address if: (i) transmission type of the first OSI layer two packet is unicast, (ii) the destination address of the first OSI layer two packet is a predefined address, and/or (iii) the first OSI layer two packet had been encapsulated in a first OSI layer three packet which is received by the first communications system at a pre-defined port;

if the destination address of the first OSI layer two packet is a broadcast or multicast address, and the broadcast or multicast address is not a predefined broadcast or multicast address: (i) converting the broadcast or multicast address to a first unicast address; (ii) sending the second OSI layer two packet to the first unicast address through a second network interface according to predefined rules;

wherein content of the second OSI layer two packet is based on content of the first OSI layer two packet;

wherein the predefined rules may be determined based on the origin of the first OSI layer two packet; and

wherein when the first OSI layer two packet is encapsulated in an OSI layer three packet, the second OSI layer two packet is sent without being encapsulated in an OSI layer three packet; and wherein when the first OSI layer two packet is not encapsulated in any OSI layer three packet, the second OSI layer two packet is sent and encapsulated in at least one OSI layer three packet.

2. The method of claim **1**, wherein when the destination address of the first OSI layer two packet is a second predefined broadcast or multicast address, not sending the second OSI layer two packet to the second predefined broadcast or multicast address.

3. The method of claim **1**, wherein the first OSI layer two packet encapsulates an Internet Protocol (IP) Address Resolution Protocol (ARP) packet, wherein the ARP packet is an ARP probe, ARP announcement or ARP reply, wherein when the ARP packet is an ARP probe or ARP announcement, the transmission type of the first OSI layer two packet is broadcast or multicast;

wherein when the ARP packet is an ARP reply, the transmission type of the first OSI layer two packet is unicast, and IP address and MAC address pair of the ARP reply is stored.

4. The method of claim **1**, wherein the first unicast address is determined by performing the steps:

listening to a specific User Data Protocol (UDP) port;

sending a first EDP packet with a predefined content to the specific UDP port of a second communication system, wherein IP address of the second communication system is determined using Dynamic Host Configuration Protocol (DHCP) or predetermined configuration;

receiving a second UDP packet from the second communication system;

if content of the second UDP packet matches a predefined content, storing a layer two source address of the second UDP packet;

determining the unicast address to be same as the layer two source address of the second UDP packet.

5. The method of claim **1**, wherein the first OSI layer two packet encapsulates an IP Dynamic Host Configuration Protocol (DHCP) packet, wherein DHCP packet is a discovery, offer, request, acknowledgement, information or releasing packet.

6. The method of claim **1**, wherein the first OSI layer two packet and the second OSI layer two packet comprise with one or more of the following wireless communication standards: High-Speed Packet Access (HSPA), HSPA+, Long Term Evolution (LTE), WiMax, GPRS, EDGE, GSM, CDMA, WiFi, CDMA2000, WCDMA, TD-SCDMA, BLUETOOTH, and WiBRO.

7. The method of claim **1**, wherein the determining of the transmission type is performed by examining a layer two destination address of the first OSI layer two packet and/or port number of layer three packets encapsulating the first OSI layer two packet; or examining information stored in a payload of the first OSI layer two packet.

8. The method of claim **1**.

(a) wherein when the first communication system is a tunnel termination gateway, and the first OSI layer two packet is received from an access point (AP) through a tunnel:

(i) the first OSI layer two packet is encapsulated in an AP layer three packet, and a computer layer three packet is encapsulated in the first OSI layer two packet;

(ii) when the destination address of the first OSI layer two packet is a first predefined broadcast or multicast address, the second OSI layer two packet is sent to the first predefined broadcast or multicast address: wherein the second OSI layer two packet is sent without being encapsulated in any AP layer three packet, and the computer layer three packet is encapsulated in the second OSI layer two packet; wherein the destination address of the second OSI layer two packet is the first predefined broadcast or multicast address;

(iii) when the destination address of the first OSI layer two packet is not a predefined broadcast or multicast address, the second OSI layer two packet is sent to a unicast address; wherein the second OSI layer two packet is sent without being encapsulated in any AP layer three packet, and the computer layer three packet is encapsulated in the second OSI layer two packet; wherein the destination address of the second OSI layer two packet is a unicast layer two address:

(b) wherein when the first communication system is a tunnel termination gateway, and the first OSI layer two packet is received through a private network:

(i) when the destination address of the first OSI layer two packet is a predefined broadcast or multicast address, the tunnel termination gateway determines whether the first OSI layer two packet is intended for broadcasting or multicasting, and the second OSI layer two packet is not sent to the predefined broadcast or multicast address;

(ii) when the destination address of the first OSI layer two packet is not a predefined broadcast or multicast address, the second OSI layer two packet is sent to a unicast address; wherein the second OSI layer two packet is encapsulated in a tunnel layer three packet, and the computer layer three packet is encapsulated in the second OSI layer two packet; wherein the destination address of the second OSI layer two packet is a specific unicast layer two address;

(c) wherein when the first communication system is an access point (AP), and the first OSI layer two packet is received from a first computing device through a layer two network:

(i) when the destination address of the first OSI layer two packet is a first predefined broadcast or multicast address, the second OSI layer two packet is sent to a tunnel termination gateway with a broadcast or multicast transmission type; wherein the destination address of the second OSI layer two packet is the first predefined broadcast or multicast address and the first predefined broadcast or multicast address is reachable through the tunnel termination gateway; wherein the second OSI layer two packet is sent after encapsulating it in an AP layer three packet, and a computer layer three packet is encapsulated in the second OSI layer two packet; wherein the destination address of the AP layer three packet is a layer three address of the tunnel termination gateway;

(ii) when the destination address of the first OSI layer two packet is not a predefined broadcast or multicast address, the second OSI layer two packet is sent to a unicast address; wherein destination address of the second OSI layer two packet is same as the destination address of the first OSI layer two packet: wherein the second OSI layer two packet is sent after being encapsulated in an AP layer three packet, and the computer layer three packet is encapsulated in the second OSI layer two packet:

(d) wherein when the first communication system is an access point (AP), and the first OSI layer two packet is received through the Internet:

(i) when the destination address of the first OSI layer two packet is a first predefined broadcast or multicast address, deciding whether to send or not to send the second OSI layer two packet to the first predefined broadcast or multicast address based on preference of an administrator; wherein the first OSI layer two packet is encapsulated in a tunnel layer three packet, and a computer layer three packet is encapsulated in the first OSI layer two packet; wherein if it is decided to send the second OSI layer two packet to the first predefined broadcast or multicast address, the second OSI layer two packet is sent without being encapsulated in any layer three packet, and the computer layer three packet is encapsulated in the second OSI layer two packet;

(ii) when the destination address of the first OSI layer two packet is not a predefined broadcast or multicast address and is the address of a second computing device, which is directly connected and is reachable without going through the Internet, the second OSI layer two packet is sent to a unicast address of the second computing device; wherein destination address of the second OSI layer two packet is same as the destination address of the first OSI layer two packet: wherein the first OSI layer two packet is encapsulated in a tunnel layer three packet, and a computer layer three packet is encapsulated in the first OSI layer two packet; wherein the second OSI layer two packet is sent without being encapsulated in any layer three packet, and the computer layer three packet is encapsulated in the second OSI layer two packet.

9. The method of claim **1**, wherein the first unicast address is determined from an input of a network administrator, determined by querying a device with a pre-configured address, or determined from a response received after sending a predefined layer three packet.

10. The method of claim **1**, wherein when transmission type of the second OSI layer two packet is broadcast or multicast and the second OSI layer two packet is encapsulated in the at least one OSI layer three packet, port number of the at least one OSI layer three packet is set to a pre-defined value for identifying the transmission type of the second OSI layer two packet is broadcast or multicast.

11. The method of claim **1**, wherein when the first OSI layer two packet is encapsulated in the at least one OSI layer three packet, the first OSI layer two packet is received from a virtual private network (VPN), and wherein when the second OSI layer two packet is encapsulated in the at least one OSI layer three packet, the second OSI layer two packet is sent through a VPN.

12. A first communication system comprising at least two network interfaces, at least one processing unit, and a computer storage medium comprising program instructions executable by the at least one processing unit to perform the operation of:

receiving a first Open Systems Interconnection (OSI) layer two packet from a first network interface;

determining whether transmission type of the first OSI layer two packet is unicast, broadcast, or multicast transmission;

determining whether destination address of the first OSI layer two packet is a predefined broadcast or multicast address;

if the destination address of the first OSI layer two packet is a first predefined broadcast or multicast address, sending a second OSI layer two packet to the first predefined broadcast or multicast address according to predefined rules corresponding to the predefined broadcast or multicast address:

sending the second OSI layer two packet to the destination address if: (i) transmission type of the first OSI layer two packet is unicast, (ii) the destination address of the first OSI layer two packet is a predefined address, and/or (iii) the first OSI layer two packet had been encapsulated in a first OSI layer three packet which is received by the first communications system at a pre-defined port;

if the destination address of the first OSI layer two packet is a broadcast or multicast address, and the broadcast or multicast address is not a predefined broadcast or multicast address: (i) converting the broadcast or multicast address to a first unicast address; (ii) sending the second OSI layer two packet to the first unicast address through a second network interface according to predefined rules;

wherein content of the second OSI layer two packet is based on content of the first OSI layer two packet;

wherein the predefined rules may be determined based on the origin of the first OSI layer two packet; and

wherein when the first OSI layer two packet is encapsulated in an OSI layer three packet, the second OSI layer two packet is sent without being encapsulated in an OSI layer three packet; and wherein when the first OSI layer two packet is not encapsulated in any OSI layer three packet, the second OSI layer two packet is sent and encapsulated in at least one OSI layer three packet.

13. The communication system of claim **12**, wherein when the destination address of the first OSI layer two packet is a second predefined broadcast or multicast address, not sending the second OSI layer two packet to the second predefined broadcast or multicast address.

14. The communication system of claim **12**, wherein the first OSI layer two packet encapsulates an Internet Protocol (IP) Address Resolution Protocol (ARP) packet, wherein the ARP packet is an ARP probe, ARP announcement or ARP reply, wherein when the ARP packet is an ARP probe or ARP announcement, the transmission type of the first OSI layer two packet is broadcast or multicast;

wherein when the ARP packet is an ARP reply, the transmission type of the first OSI layer two packet is unicast, and IP address and MAC address pair of the ARP reply is stored.

15. The communication system of claim **12**, wherein the first unicast address is determined by performing the steps:

listening to a specific User Data Protocol (UDP) port;

sending a first UDP packet with a predefined content to the specific UDP port of a second communication system, wherein IP address of the second communication system is determined using Dynamic Host Configuration Protocol (DHCP) or predetermined configuration;

receiving a second UDP packet from the second communication system;

if content of the second UDP packet matches a predefined content, storing a layer two source address of the second UDP packet;

determining the unicast address to be same as the layer two source address of the second UDP packet.

16. The communication system of claim **12**, wherein the first OSI layer two packet encapsulates an IP DHCP packet wherein DHCP packet could be discovery, offer, request, acknowledgement, information or releasing packet.

17. The communication system of claim **12**, wherein the first OSI layer two packet and the second OSI layer two packet comprise with one or more of the following wireless communication standards: High-Speed Packet Access (HSPA), HSPA+, Long Term Evolution (LTE), WiMax, GPRS, EDGE, GSM, CDMA, WiFi, CDMA2000, WCDMA, TD-SCDMA, BLUETOOTH, and WiBRO.

18. The communication system of claim **12**, wherein the determining of the transmission type is performed by examining a layer two destination address of the first OSI layer two packet and/or port number of layer three packets encapsulating the first OSI layer two packet: or examining information stored in a payload of the first OSI layer two packet.

19. The communication system of claim **12**,

(a) wherein when the first communication system is a tunnel termination gateway, and the first OSI layer two packet is received from an access point (AP) through a tunnel:

(i) the first OSI layer two packet is encapsulated in an AP layer three packet, and a computer layer three packet is encapsulated in the first OSI layer two packet;

(ii) when the destination address of the first OSI layer two packet is a first predefined broadcast or multicast address, the second OSI layer two packet is sent to the first predefined broadcast or multicast address; wherein the second OSI layer two packet is sent without being encapsulated in any AP layer three packet, and the computer layer three packet is encapsulated in the second OSI layer two packet; wherein the destination address of the second OSI layer two packet is the first predefined broadcast or multicast address;

(iii) when the destination address of the first OSI layer two packet is not a predefined broadcast or multicast address, the second OSI layer two packet is sent to a unicast address; wherein the second OSI layer two packet is sent without being encapsulated in any AP layer three packet, and the computer layer three packet is encapsulated in the second OSI layer two packet; wherein the destination address of the second OSI layer two packet is a unicast layer two address;

(b) wherein when the first communication system is a tunnel termination gateway, and the first OSI layer two packet is received through a private network:

(i) when the destination address of the first OSI layer two packet is a predefined broadcast or multicast address, the tunnel termination gateway determines whether the first OSI layer two packet is intended for broadcasting or multicasting, and the second OSI layer two packet is not sent to the predefined broadcast or multicast address;

(ii) when the destination address of the first OSI layer two packet is not a predefined broadcast or multicast address, the second OSI layer two packet is sent to a unicast address; wherein the second OSI layer two packet is encapsulated in a tunnel layer three packet, and the computer layer three packet is encapsulated in the second OSI layer two packet; wherein the destination address of the second OSI layer two packet is a specific unicast layer two address:

(c) wherein when the first communication system is an access point (AP), and the first OSI layer two packet is received from a first computing device through a layer two network:

(i) when the destination address of the first OSI layer two packet is a first predefined broadcast or multicast address, the second OSI layer two packet is sent to a tunnel termination gateway with a broadcast or multicast transmission type: wherein the destination address of the second OSI layer two packet is the first predefined broadcast or multicast address and the first predefined broadcast or multicast address is reachable through the tunnel termination gateway; wherein the second OSI layer two packet is sent after encapsulating it in an AP layer three packet, and a computer layer three packet is encapsulated in the second OSI layer two packet; wherein the destination address of the AP layer three packet is a layer three address of the tunnel termination gateway;

(ii) when the destination address of the first OSI layer two packet is not a predefined broadcast or multicast address, the second OSI layer two packet is sent to a unicast address; wherein destination address of the second OSI layer two packet is same as the destination address of the first OSI layer two packet; wherein the second OSI layer two packet is sent after being encapsulated in an AP layer three packet, and the computer layer three packet is encapsulated in the second OSI layer two packet;

(d) wherein when the first communication system is an access point (AP), and the first OSI layer two packet is received through the Internet:

(i) when the destination address of the first OSI layer two packet is a first predefined broadcast or multicast address, deciding whether to send or not to send the second OSI layer two packet to the first predefined broadcast or multicast address based on preference of an administrator; wherein the first OSI layer two packet is encapsulated in a tunnel layer three packet, and a computer layer three packet is encapsulated in the first OSI layer two packet; wherein if it is decided to send the second OSI layer two packet to the first predefined broadcast or multicast address, the second OSI layer two packet is sent without being encapsulated in any layer three packet, and the computer layer three packet is encapsulated in the second OSI layer two packet;

(ii) when the destination address of the first OSI layer two packet is not a predefined broadcast or multicast address and is the address of a second computing device, which is directly connected and is reachable without going through the Internet, the second OSI layer two packet is sent to a unicast address of the second computing device; wherein destination address of the second OSI layer two packet is same as the destination address of the first OSI Layer two packet; wherein the first OSI layer two packet is encapsulated in a tunnel layer three packet, and a computer layer three packet is encapsulated in the first OSI layer two packet; wherein the second OSI layer two packet is sent without being encapsulated in any layer three packet, and the computer layer three packet is encapsulated in the second OSI layer two packet.

20. The communication system of claim **12**, wherein the first unicast address is determined from an input of a network administrator, determined by querying a device with a pre-configured address, or determined from a response received after sending a predefined layer three packet.

21. The communication system of claim **12**, wherein when transmission type of the second OSI layer two packet is broadcast or multicast and the second OSI layer two packet is encapsulated in the at least one OSI layer three packet, port number of the at least one OSI layer three packet is set to a pre-defined value for identifying the transmission type of the second OSI layer two packet is broadcast or multicast.

22. The communication system of claim **12**, wherein when the first OSI layer two packet is encapsulated in the at least one OSI layer three packet, the first OSI layer two packet is received from a virtual private network (VPN) and wherein when the second OSI layer two packet is encapsulated in the at least one OSI layer three packet, the second OSI layer two packet is sent through a VPN.

23. The communication system of claim **22**, wherein the communication system is comprises at least one OSI layer three router and at least ne OSI layer two switch; wherein the at least one OSI layer three router is used for establishing layer two tunnels using layer three communication technologies; and wherein the at least one OSI layer two switch is used for determining whether to send the second OSI layer two packet, transmission type of the second OSI layer two packet, and destination address of the second OSI layer two packet.

24. The communication system of claim **22**, wherein one of the at least two network interface further comprises an 802.11 interface and another one of the at least two network interface further comprises 802.16 interface.

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