



US009571301B2

(12) **United States Patent**  
Norris et al.

(10) **Patent No.:** US 9,571,301 B2  
(45) **Date of Patent:** \*Feb. 14, 2017

(54) **SYSTEM AND METHOD FOR A MULTI-TENANT DATACENTER WITH LAYER 2 CLOUD INTERCONNECTION**

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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 1017 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **13/356,555**

(22) Filed: **Jan. 23, 2012**

(65) **Prior Publication Data**

US 2013/0188512 A1 Jul. 25, 2013

(51) **Int. Cl.**

**H04L 12/28** (2006.01)

**H04L 12/46** (2006.01)

**H04L 29/08** (2006.01)

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

CPC ..... **H04L 12/4641** (2013.01); **H04L 67/10** (2013.01); **H04L 12/465** (2013.01)

(58) **Field of Classification Search**

CPC ..... G06F 9/5061; G06F 2009/45595; G06F 9/45558; G06F 9/45533; H04L 61/6022; H04L 12/462; H04L 12/4662; H04L 12/4633; H04L 12/4641; H04L 12/4625; H04L 29/12018; H04L 45/04; H04L 45/66; H04L 49/70  
USPC ..... 370/254, 217, 395.53; 718/1; 726/4; 709/223, 232

See application file for complete search history.

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Primary Examiner — Chi H Pham

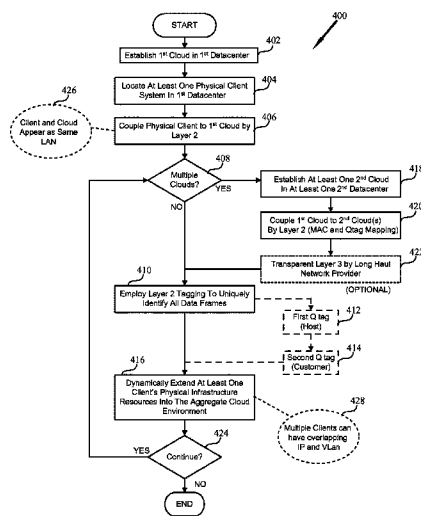
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(57) **ABSTRACT**

Provided is a system and method for a multi-tenant datacenter with layer 2 cloud interconnection. More specifically the multi-tenant datacenter includes a plurality of physical client systems in a first datacenter each physical client system having a set of physical infrastructure resources. A first cloud computing environment is also in the first datacenter, and coupled to the physical client systems by OSI Layer 2. The first cloud computing environment thereby virtually extending the physical infrastructure resources of each physical client system. An associated method of providing a multi-tenant datacenter with layer 2 cloud interconnection is also provided.

**31 Claims, 8 Drawing Sheets**



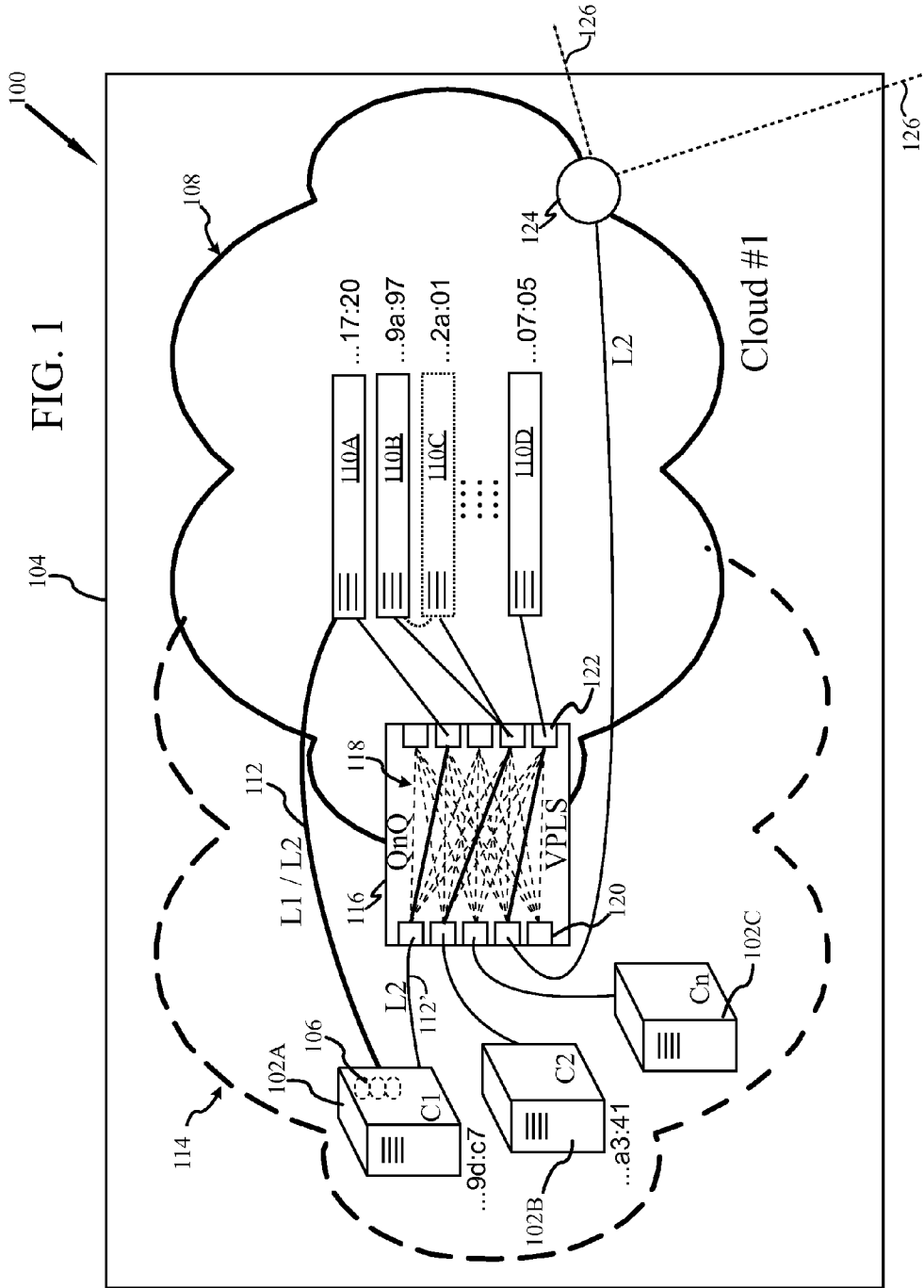


FIG. 1

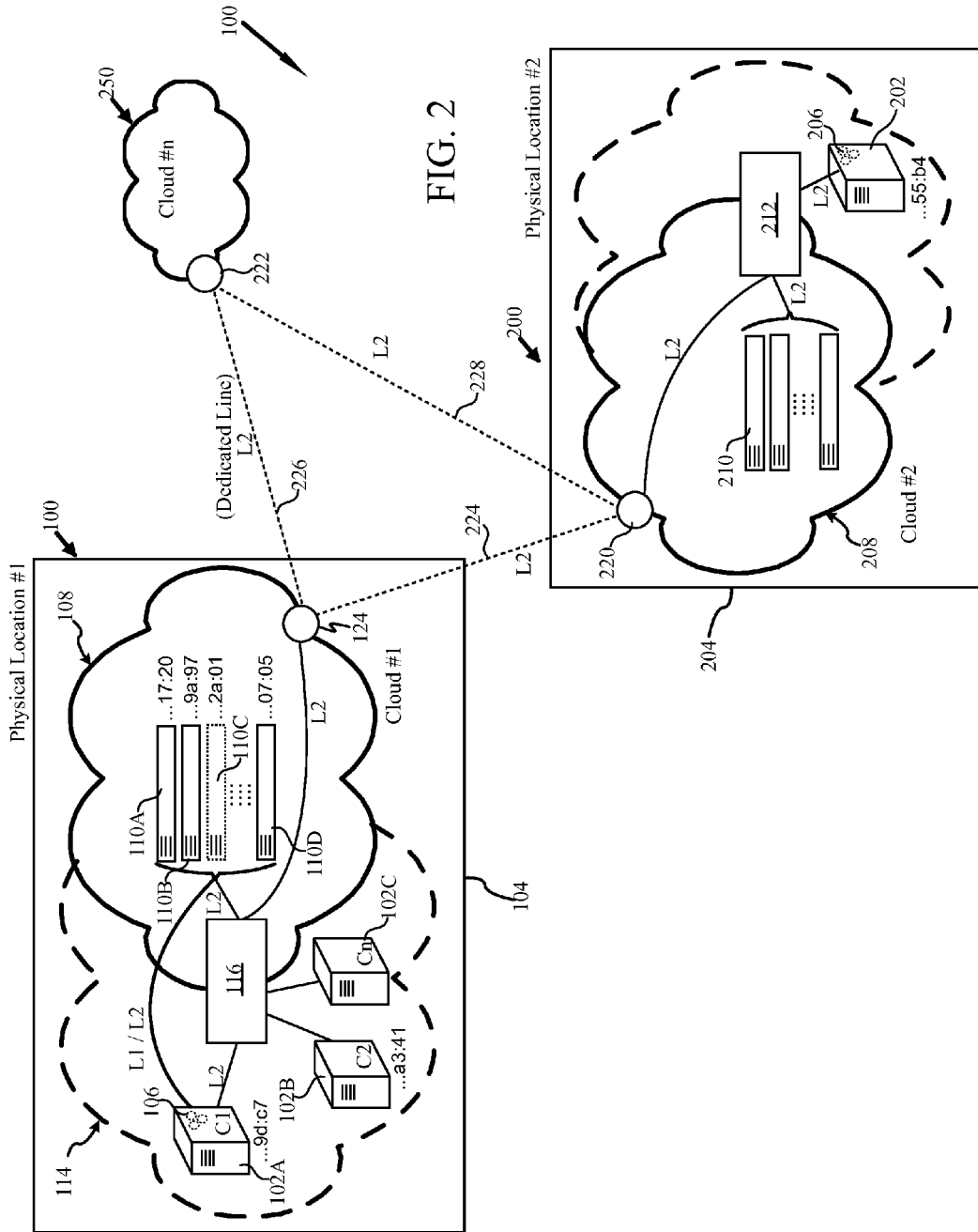


FIG. 2

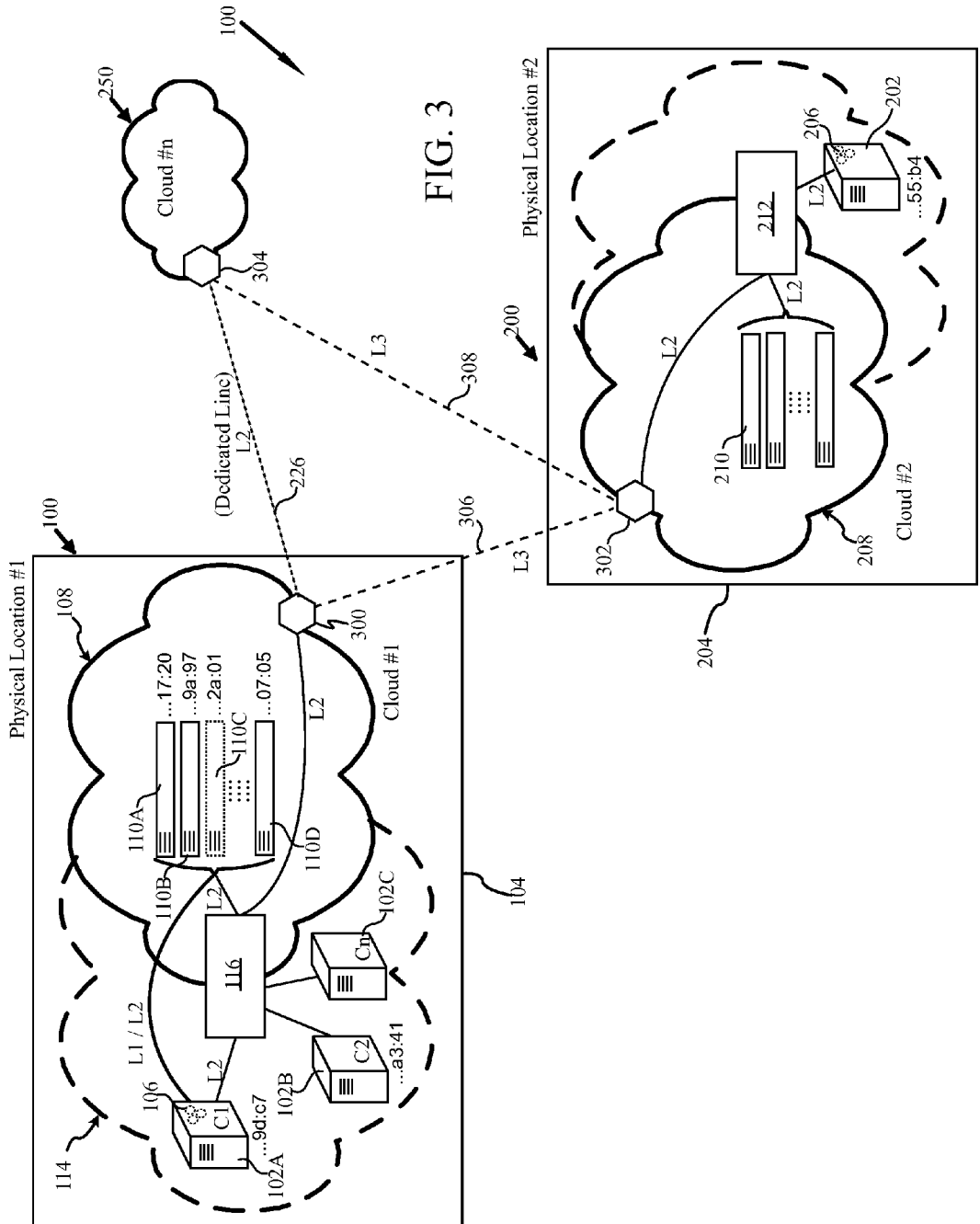
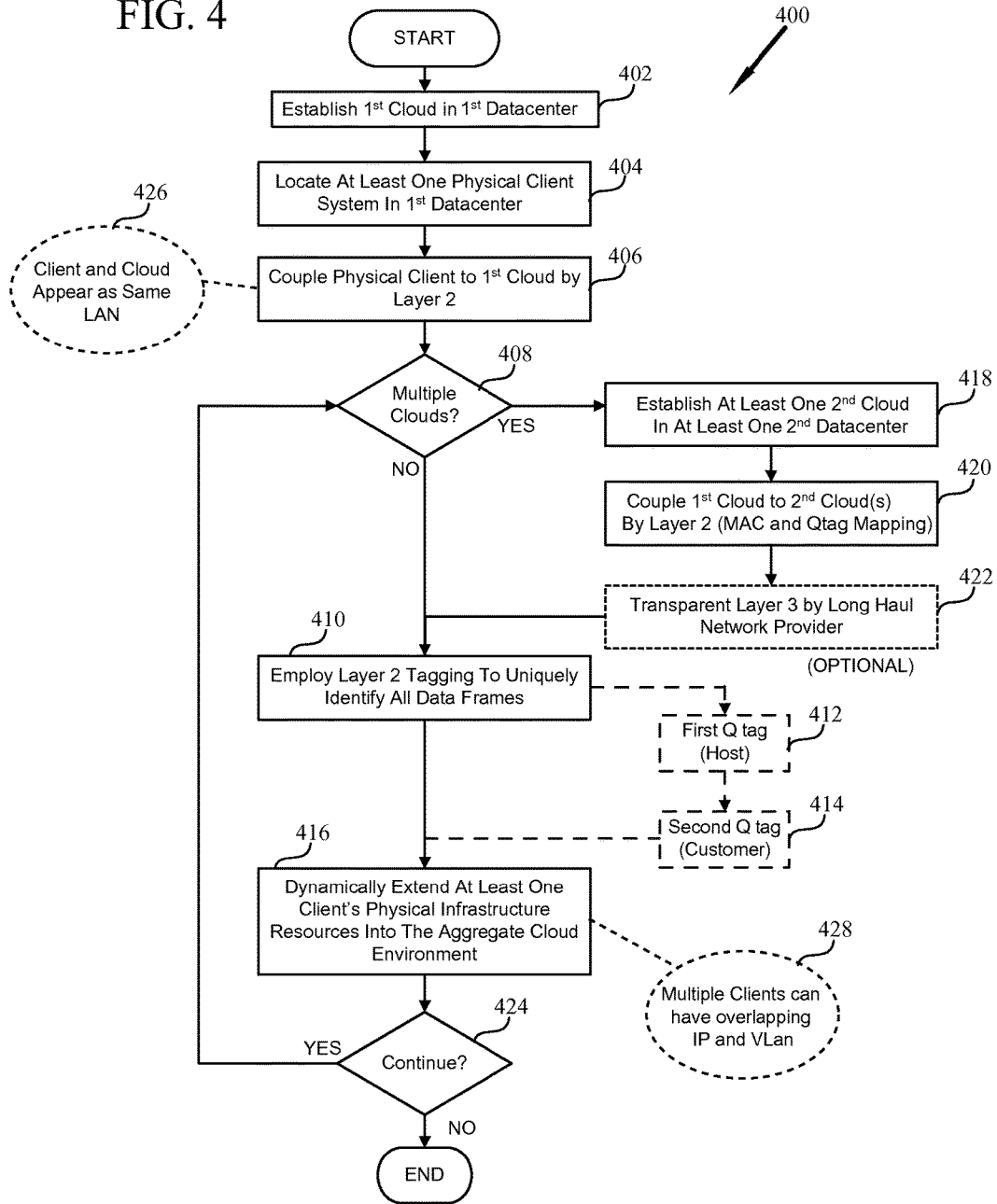


FIG. 3

FIG. 4



500 ↗

FIG. 5

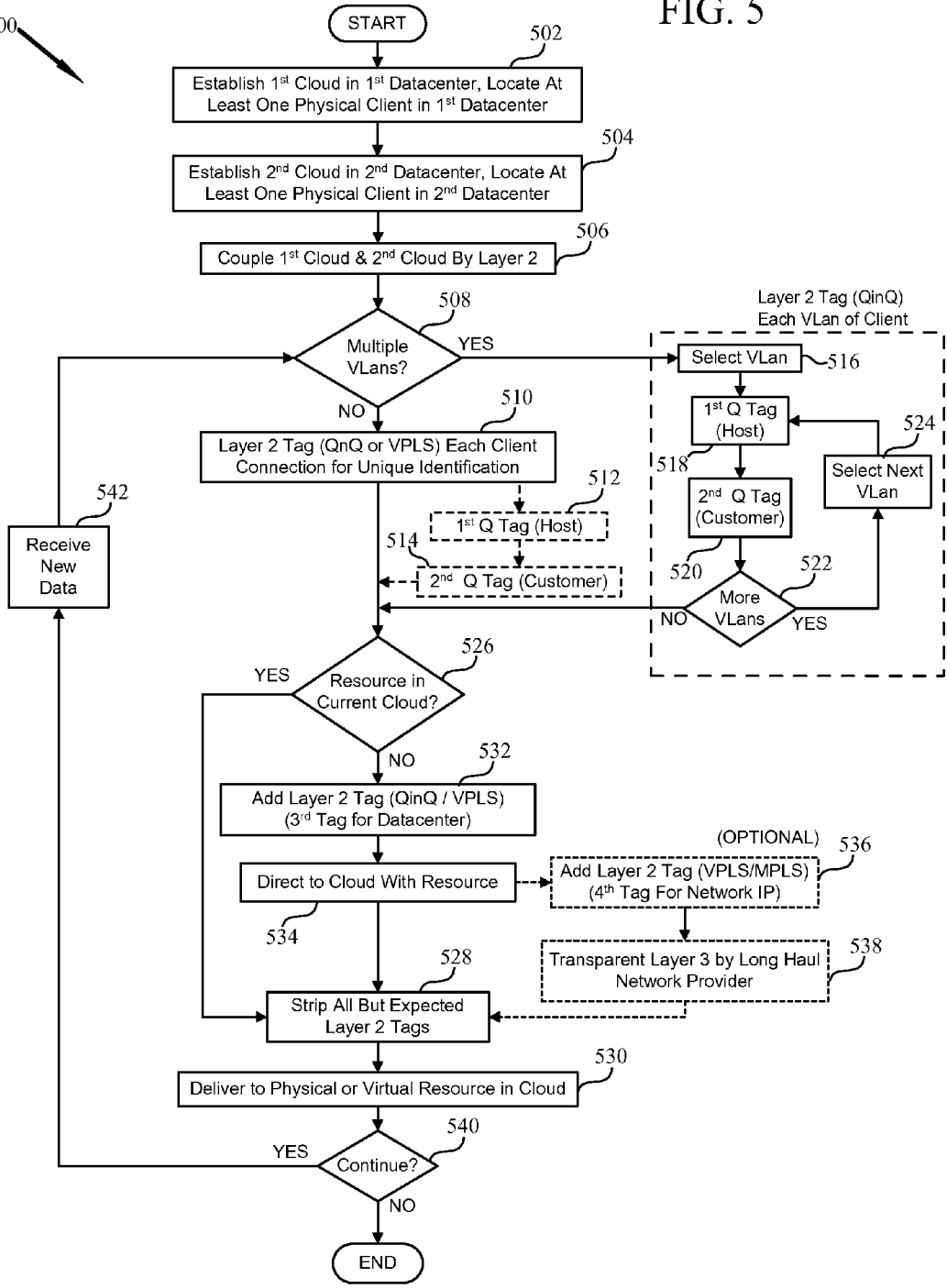


FIG. 6

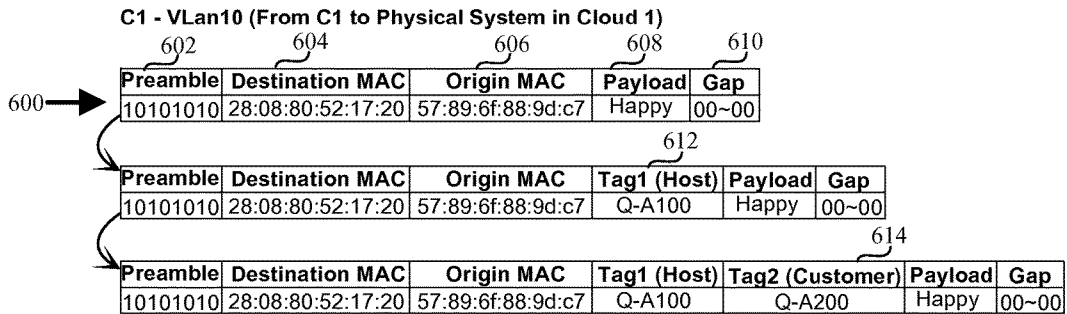


FIG. 7

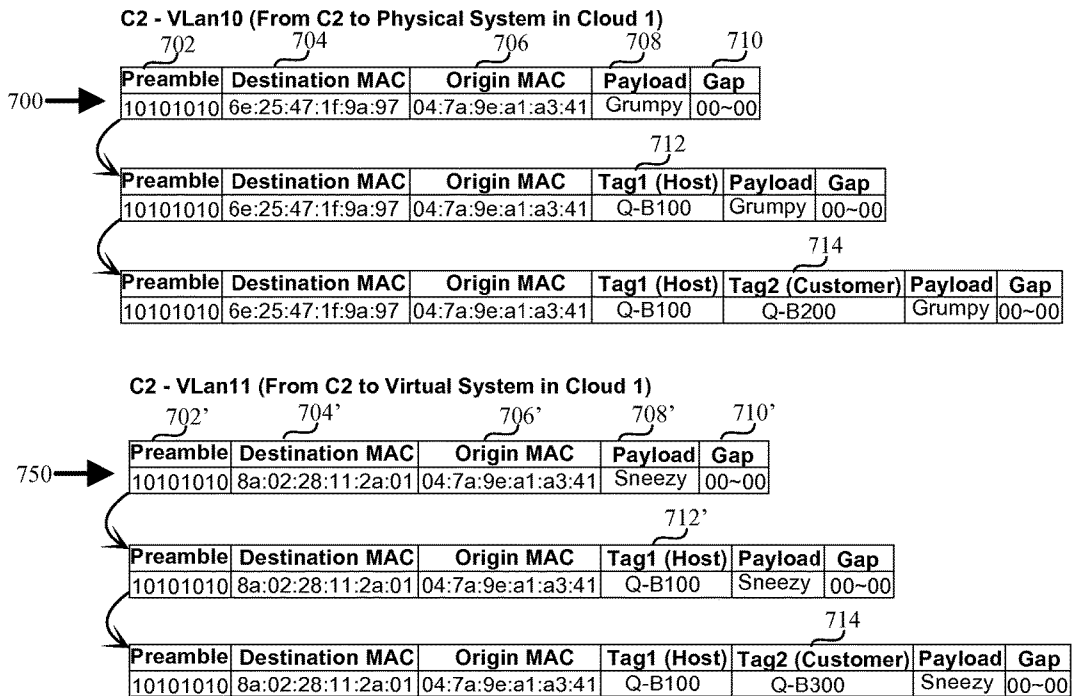


FIG. 8

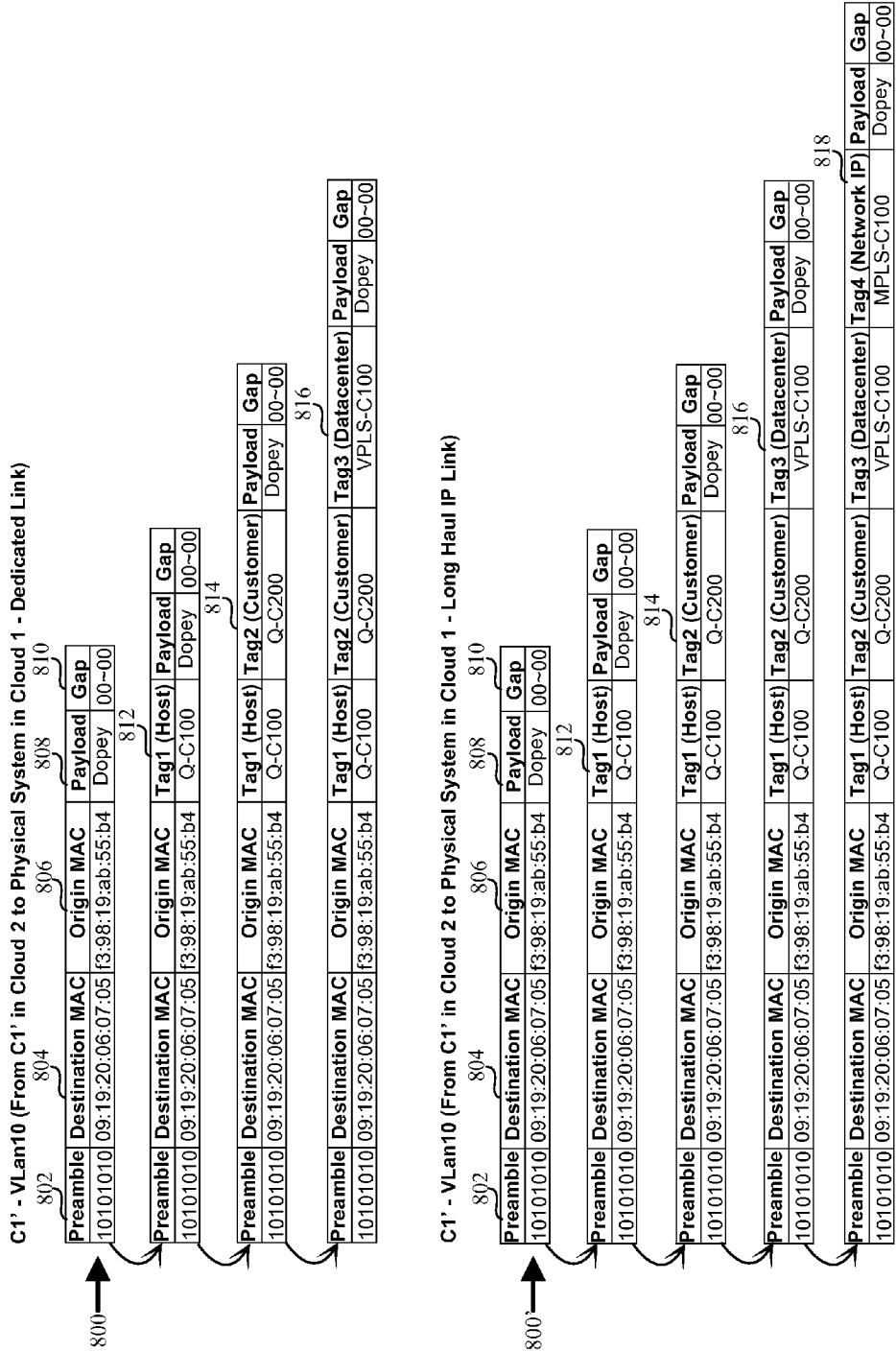
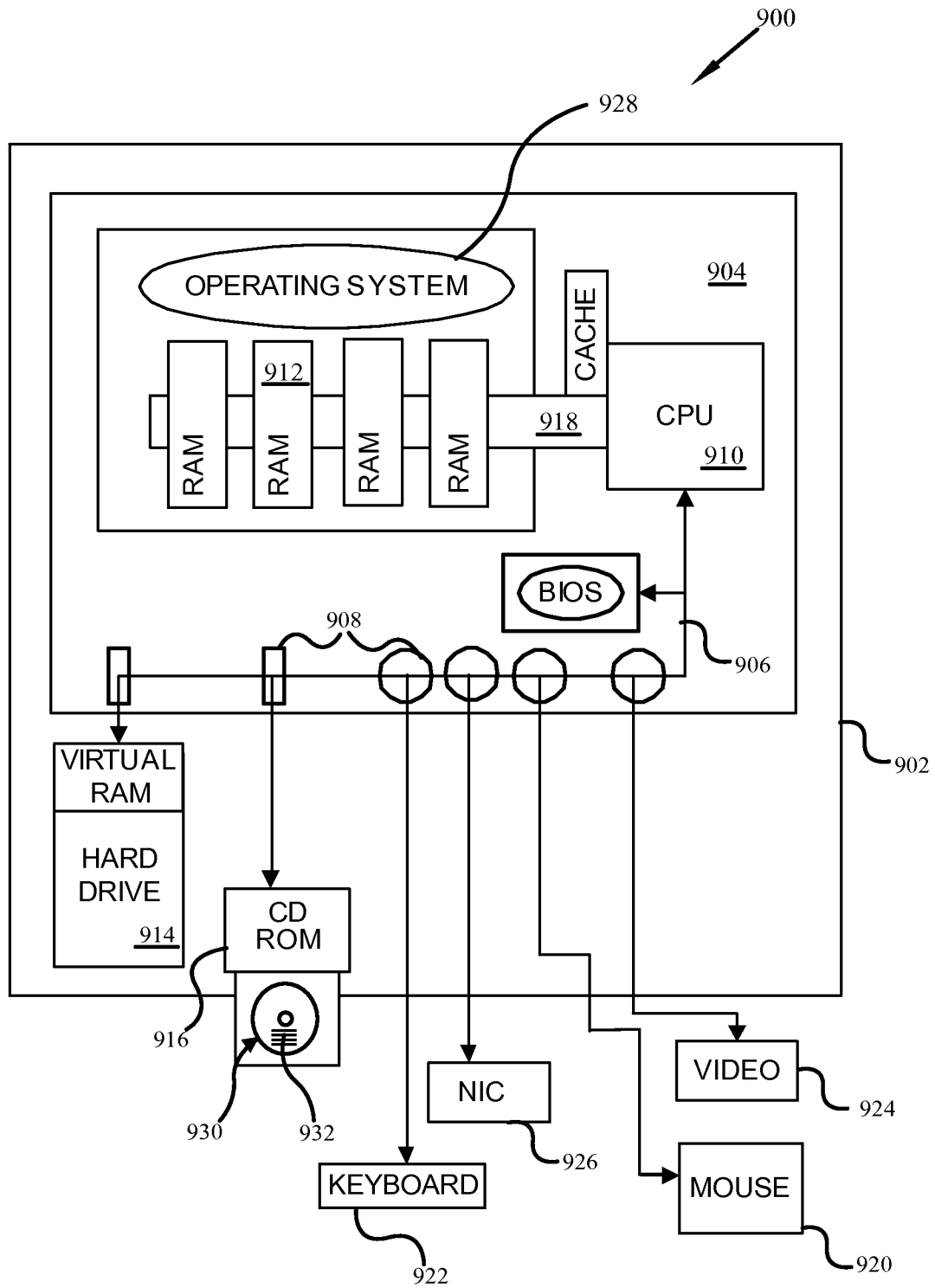




FIG. 9



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# SYSTEM AND METHOD FOR A MULTI-TENANT DATACENTER WITH LAYER 2 CLOUD INTERCONNECTION

## CROSS-REFERENCE TO RELATED APPLICATIONS

None.

## FIELD OF THE INVENTION

The present invention relates generally to systems and methods for flexible network infrastructure, and more specifically to a multi-tenant datacenter with Layer 2 cloud interconnection.

## BACKGROUND

Computer systems, and more specifically networked computer systems are a center point of modern society. Advances in production and miniaturization have permitted the production of increasingly faster processors and larger data storage.

Commerce, and indeed business in general is highly reliant on networked computer systems for nearly all aspects of business activity, such as but not limited to offering products for sale, maintaining account records, analyzing data, etc . . . . Yet, the needs for resources may and often do change from time to time.

Networks exist in a variety of forms, from the vast and expansive nature of the Internet to the small local area network of a company or home setting. Whereas it was once commonplace to provide all desired computer resources within one physical system, networking systems permit a greater flexibility in adaptively balancing resources and scaling to meet needs. Network connection and integration requires an ability for the elements, e.g. systems, of the intended network to find and communicate with each other.

The Open System Interconnection model, also referred to as the Open Source Interconnection model or more simply the OSI model, is a product of the Open System Interconnection effort at the International Organization for Standardization, and more specifically is a prescription of characterizing and standardizing the functions of a communication system in terms of seven abstraction layers of concentric organization—Layer 1 the physical layer, Layer 2 the data link layer, Layer 3 the network layer, Layer 4 the transport layer, Layer 5 the session layer, Layer 6 the presentation layer, and Layer 7 the application layer.

Each layer is generally known as an N Layer. At each layer, two entities, i.e., N-entity peers, interact by means of the N protocol by transmitting protocol data units or “PDU”. A Service Data Unit “SDU” is a specific unit of data that has been passed down from one layer to another, and for which the lower layer has not yet encapsulated into a PDU. Moreover the PDU of any given layer, Layer N, is the SDU of the layer below, layer N-1. In other words, the SDU is the payload of a given PDU.

Transfer of an SDU between layers is therefore a matter of encapsulation and is performed by the lower layer in adding appropriate headers and or footers to the SDU such that it becomes a PDU. These headers and or footers are part of the communication process permitting data to get from a source to a destination within any network.

Briefly, Layer 1, the physical layer defines the electrical and physical specifications of the device and the communication medium, e.g., copper cable, optical cable, wireless,

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etc. Layer 2, the data link layer, provides the functional and procedural means to transfer data from one entity to another, and to possibly correct errors that may occur in the physical layer. The data is arranged in logical sequences known as frames.

Layer 3 is the network layer and provides the functional and procedural means of transferring variable length data sequences from a source on one network to a destination host on a different network. Routers operate at this layer and make the Internet possible by properly handling the interconnections and handoffs between different networks. Layer 4 is the transport layer responsible for data transfer between end users and the reliability of a given link through flow control, segmentation/desegmentation and error control.

Layers 5, 6 and 7 as the Session, Presentation and Application layer are successively higher and closer to the user and subsequently further and further away from the physical layer. The greater the number of transfers between layers to accomplish any given task, the greater the complexity, latency and general opportunity for error.

Indeed within a typical local area network (LAN), wherein the systems are indeed part of the same network, the communication of data transfer is generally accomplished at the Layer 2 level. However, when joining one LAN to another, or to a wide area network (WAN), the addresses of the LAN may be meaningless or perhaps even duplicative of other addresses in other LANs and as such the translation to Layer 3 is the generally accepted method for maintaining harmony in communication.

While this is a viable option, and indeed the existence of the Internet demonstrates overall functionality, it does often come with overhead costs and burdens of complexity. For example, whereas a database within a LAN may be communicated with via Layer 2 and thereby enjoy enhanced integration as a networked component, accessing a similar database over Layer 3 requires Internet Protocol “IP” address translation, or other similar transformation which by its vary nature requires the originating system to be configured for, and perhaps engage in appropriate measures for proper identification, and addressing of data to and from the remote database as would not be otherwise required with a LAN based database. For example the LAN systems may be on one network or VLAN and the remote database is part of another network or VLAN—the differences requiring at the very least a router to adjust and account for the differences in network identity and configuration.

Indeed, while remote services do provide a lower cost option to the direct acquisition of hardware and thereby permit enhanced scalability of resources in response to needs, the remote services as offered to a plurality of needy parties are not perceived by each party simply as an extension of his or her existing resources.

One form of remote service is that of cloud computing, wherein a collection of physical systems provide both physical and virtualized resources. Although gaining in popularity, cloud computing and the integration of these resources is performed at Layer 3 so as to permit the generally accepted methodologies of IP protocol translations to insure proper segregation of data.

Moreover, as many LANs are configured with default options it is very common for multiple end users to have the same local IP addresses within their various networks. For connection to and utilization of a traditional cloud environment network address translation must be employed—a requirement that is often beyond the skills and capability of the end user. When the needs for such resources are dynamic, such continual adjustments and additions through

Layer 3 IP addresses can be taxing in terms of time, costs, and possible error among other factors.

Further, the resources of a cloud environment are also generally limited due to one or more physical constraints. Although perhaps expandable to a point, such expansion cannot generally be achieved in real time as at some point additional physical systems must be installed, configured and integrated. And again, once such systems have been integrated, if the need for resources diminishes they cannot easily be taken out of use without again physical interaction.

Moreover, although cloud computing does provide an improvement in many ways over previous options for expansion and contraction of resources to meet needs, it is not without its own set of challenges and difficulties.

It is to innovations related to this subject matter that the claimed invention is generally directed.

### SUMMARY

Embodiments of this invention provide a system and method for a multi-tenant datacenter with Layer 2 cloud interconnection.

In particular, and by way of example only, according to one embodiment of the present invention, provided is a multi-tenant datacenter, including: a plurality of physical client systems in a first datacenter each physical client system having a set of physical infrastructure resources; a first cloud computing environment established in the first datacenter, and coupled to the physical client systems by OSI Layer 2, the first cloud computing environment thereby virtually extending the physical infrastructure resources of each physical client system.

In another embodiment, provided is a method for providing a multi-tenant datacenter, including: establishing within a first datacenter a first cloud computing environment; locating at least one physical client systems in the first datacenter, each physical client having a set of physical infrastructure resources; and coupling the at least one physical client system to the first cloud computing environment by OSI Layer 2, the OSI Layer 2 coupling virtually extending the physical infrastructure resources of each physical client system.

In yet another embodiment, provided is a method for providing a multi-tenant datacenter, including: establishing within a first datacenter a first cloud computing environment; locating a plurality of physical client system in the first datacenter, each physical client system having a set of physical infrastructure resources; and uniquely identifying data traffic as between each client system and the first cloud computing environment by a plurality of OSI Layer 2 tags as unique identifiers permitting unique identification for each client system of at least one host and a customer.

Still further, in another embodiment, provided is a method for providing a multi-tenant datacenter, including: establishing within a first datacenter a first cloud computing environment having first physical resources and first virtual resources; establishing within a second datacenter a second cloud computing environment having second physical resources and second virtual resources; and coupling the first cloud computing environment to the second cloud computing environment by OSI Layer 2.

### BRIEF DESCRIPTION OF THE DRAWINGS

At least one system and method for a multi-tenant datacenter with Layer 2 cloud interconnection will be described, by way of example in the detailed description below with

particular reference to the accompanying drawings in which like numerals refer to like elements, and:

FIG. 1 illustrates a conceptual view of a multi-tenant datacenter with Layer 2 cloud interconnection in accordance with at least one embodiment of the present invention;

FIG. 2 illustrates a conceptual view of multiple multi-tenant datacenter with Layer 2 cloud interconnection interconnected in accordance with at least one embodiment of the present invention;

FIG. 3 illustrates yet another conceptual view of multiple multi-tenant datacenter with Layer 2 cloud interconnection interconnected in accordance with at least one embodiment of the present invention;

FIG. 4 illustrates a high level flow diagram depicting at least one method for a multi-tenant datacenter in accordance with at least one embodiment of the present invention;

FIG. 5 is illustrates a more refined flow diagram depicting at least one method for a multi-tenant datacenter in accordance with at least one embodiment of the present invention;

FIG. 6 illustrates an exemplary frame and its Layer 2 tagging for communication between a client system and a cloud system within a common datacenter in accordance with at least one embodiment of the present invention;

FIG. 7 illustrates yet other exemplary frames and their Layer 2 tagging for communication between a client system and a cloud system within a common datacenter in accordance with at least one embodiment of the present invention;

FIG. 8 illustrates yet other exemplary frames and their Layer 2 tagging for communication between a client system and a cloud system in different physical datacenters in accordance with at least one embodiment of the present invention; and

FIG. 9 is a block diagram of a computer system in accordance with certain embodiments of the present invention.

### DETAILED DESCRIPTION

Before proceeding with the detailed description, it is to be appreciated that the present teaching is by way of example only, not by limitation. The concepts herein are not limited to use or application with a specific of system or method for a multi-tenant datacenter with OSI Layer 2 cloud interconnection. Thus, although the instrumentalities described herein are for the convenience of explanation shown and described with respect to exemplary embodiments, it will be understood and appreciated that the principles herein may be applied equally in other types of systems and methods for multi-tenant datacenters.

Turning now to the drawings, and more specifically FIG. 1, illustrated is a high-level diagram of a multi-tenant datacenter with OSI Layer 2 cloud interconnection ("MTDC") **100** in accordance with certain embodiments.

Moreover, MTDC **100** has a plurality of physical client systems **102**, of which client system **102A** corresponding to **C1**, client system **102B** corresponding to **C2** and client system **102C** corresponding to **Cn** are exemplary. These client systems **102** are located within a first datacenter **104**. It is understood and appreciated that although depicted as single elements, each client system **102** may indeed be a racked set of physical components interconnected as a Local Area Network, LAN. Further each client system **102** has a set of physical infrastructure resources **106**, such as but not limited to one or more processors, main memory, storage memory, network interface devices, long term storage, network access, etc . . . .

A first cloud computing environment, hereinafter first cloud **108** is established in the first datacenter **104** by one or more physical and/or virtual computer systems **110**, of which systems **110A-110D** are exemplary.

More specifically, first cloud **108** is established at least in part by physical computer systems. Although improvements in manufacturing have reduced the costs associated with physical components and systems, and therefore also reduced the cost of the programmable machine, in many instances the total resources of a machine are not utilized continuously.

In light of this, in many situations it has been found that a physical machine can be adapted to provide a plurality of virtual machines/systems—each an efficient, and functional equivalent of a real physical machine. Each virtual machine/system can provide a complete system platform that supports the execution of a complete operating system and any associated applications.

Because one physical programming machine can support multiple virtual machines/systems, the cost benefits of utilizing virtual machines over individual physical machines can be advantageous. In general, each virtual machine/system is an emulation of a physical machine/system, including a virtualization of the physical components, such as storage devices, network devices, processors and the like. Systems **110A**, **110B** and **110D** are physical systems, and **110C** has been shown in dotted outline to indicate that it is a virtual system, provided by physical system **110B**.

As used herein the first cloud **108** is understood and appreciated to be a highly scalable and dynamic environment of computer resources and services that can be provided to customers, specifically the client systems **102**. In other words the first cloud **108** is structured and arranged to provide Infrastructure as a Service.

Advantageously, the first cloud **108** is coupled to the client systems **102** by OSI Layer 2. As such the first cloud **108** thereby virtually extends the physical infrastructure of the resources of each client system **102**. And, as this extension is accomplished at OSI Layer 2, the client systems **102** perceive the extended infrastructure resources as being elements of their network.

In other words, the client system **102**, generally consisting of a rack of components coupled as a LAN enjoys the resources of the first cloud **108** as if the provided resources were indeed part of the client system's LAN. This is conceptually indicated by dotted extension **114** of cloud computing environment **108**.

The coupling of the client systems **102** and the first cloud **108** is achieved through the physical connection of a data channel for the transfer of data frames. This physical connection of a data channel is an OSI Layer 1 interconnection, e.g., wire, fiber, wireless or other appropriate physical data channel.

The frame is a digital data transmission unit or data packet. In general a frame has control data used to deliver the packet and payload data. At OSI Layer 2, these frames consist of a preamble, a destination Media Access Control address (MAC address), an origin MAC address, zero or more tags, the payload data and a gap. FIG. **6** presents example frame **600**, showing preamble **602**, a destination MAC address **604** corresponding to system **110A**, an origin MAC address **606** corresponding to client system **102A**, a payload **608**, and a gap **610**. These frames as provided by the client systems do not contain the IP address of the destination resource. Similarly, these frames as provided by a first cloud **108** system for return to an associated client system **102** do not contain the IP address of the destination client.

This physical connection permitting OSI Layer 2 interconnection in MTDC **100** between the client systems **102** and the first cloud **108** should not be confused with more traditional cloud environments wherein clients connect to a cloud by way of some data channel but data exchange is knowingly and intentionally handled at OSI Layer 3 or above. Such connections do not seamlessly and transparently blend the client systems **102** and first cloud **108** systems **110** together as is achieved in MTDC **100**.

With respect to FIG. **1**, for at least one embodiment, the client systems **102**, such as client system **102A** are connected directly to a system **110**, as shown by L1/L2 connection link **112**, indicating an OSI Layer 1 or OSI Layer 2 link. Although viable, with a large plurality of client systems **102**, such direct connection permits limited scalability. Moreover, for at least one alternative embodiment, the client systems **102** are coupled to the first cloud **108** by at least one switch **116**. These connections are OSI Layer 2 connections as indicated by the L2 links **112**.

The use of the switch **116** is quite specific and distinct from the use of a router. A router is intended for traditionally interconnecting different networks, e.g., a Level 3 operation. A switch on the other hand is intended to connect computing devices together within one LAN. Each client system **102** is connected to the switch **116** and a map **118** is established within the switch **116** to properly interconnect each client system **102** with the physical or virtual system **110** providing the intended infrastructure resources. For ease of illustration and discussion, this map **118** is conceptually shown as solid and dashed connections as between the ports **120** to which the client systems **102** are connected and the ports **122** to which the physical or virtual systems **110** are connected.

As indicated above, the coupling of the client systems **102** to the first cloud **108** is by the transfer of frames over the physical interconnection. To achieve the transparent extension of the client system **102** infrastructure resources, for at least one embodiment a plurality of OSI Layer 2 tags are employed with each frame. These OSI Layer 2 tags advantageously permit the identification for each client system **102** of a host system and a customer system. Further, these OSI Layer 2 tags are employed transparently by the MTDC **100** such that the client systems **102** advantageously are permitted to operate without need for purposeful transformation or adjustment to their respective LAN environments for participation in the first cloud **108**.

In other words client system **102A** may have an IP range set to the rather typical default of 192.168.0.X as may client system **102B**. For a traditional cloud computing environment these default IP ranges could pose a problematic issue for with the overlapping ranges proper data intended for a system identified as 192.168.0.50, as part of client system **102A** could be inadvertently provided to a system identified as 192.168.0.50, as part of client system **102B**.

Likewise if multiple clients established Virtual local area networks, or VLANs, as default settings are often maintained, and or random selection could still permit overlapping ranges, errors in network traffic management could occur. As MTDC **100** advantageously employs OSI Layer 2 tagging and is not reliant upon IP addresses, these issues are irrelevant and each client system **102** is permitted to operate without interference.

For at least one embodiment, the OSI Layer 2 tags employed are Q tags as defined by IEEE 802.1Q. As the MTDC **100** is employing OSI Layer 2 tags to at least identify a host and customer, two (2) Q tags are generally employed at a minimum, known as QinQ tagging. More specifically, IEEE 802.1Q is understood and appreciated as

a standard for VLAN tagging. With IEEE standard 802.1ad, double-tagging can be achieved which permits mixing traffic from multiple client systems **102** that have already been tagged.

To permit the QinQ tagging, in at least one embodiment of MTDC **100**, two switches **116** may be connected in series to permit the double tagging. For at least one alternative embodiment, an enhanced switch **116** is employed that is structured and arranged to permit double Q tagging. With respect to MTDC **100** as shown in FIG. 1, when a frame enters a port, e.g., ports **120** from the client systems **102** or ports **122** from the first cloud **108** systems **110**, a tag is added to represent the VLAN membership of the frame's port and the second tag is added to represent the VLAN membership of the frame's destination port.

With respect to the exemplary frame **600** shown in FIG. 6, for the sake of example "A" series tags have been adopted to identify frames for association to client system **102A**. As such, Tag1—the host tag **612**—is shown as Q-A**100**, and Tag2—the customer tag **614**—is shown as Q-A**200**.

Moreover, for at least one embodiment, an element of the OSI Layer 2 coupling of the client systems **102** to the first cloud **108** is the mapping of the OSI Layer 2 tags such that switch **116** properly interconnects the client systems **102** with the cloud **108**, and more specifically the systems **110** within the first cloud providing the extended infrastructure. For at least one embodiment, the mapping process includes defining for each client system **102** the host and customer tags, and may well include defining additional tags which may be used, but are not limited to, identification of the datacenter **104**, i.e. cloud **108**, itself to permit proper interconnection of multiple instances MTDC **100**. The tagging process is further discussed below in connection with describing at least one method for providing MTDC **100**.

In at least one embodiment additional OSI Layer 2 tags are also employed, such as VPLS and or MPLS tags. Moreover, in varying embodiments, the OSI Layer 2 tags employed are selected from the group consisting of QinQ tags, MPLS tags, VPLS tags and combinations thereof. The use of multiple OSI Layer 2 tags can permit increased scalability as well as the ability to interconnect multiple MTDC **100** locations advantageously at OSI Layer 2. Indeed, an additional switch **124** is shown with a OSI Layer 2 connection to switch **116**. Switch **124** is structured and arranged to permit interconnection of this first instance of MTDC **100** with one or more second instances of MTDC **100** as suggested by dotted interconnection lines **126** and as further described below with respect to FIG. 2.

Moreover, the use of Layer 2 tags selected from the group consisting of, but not limited to, Q tags, QinQ tags, MPLS tags, VPLS tags, are to be understood and appreciated as options for one or more specific embodiments, and not as limitations. Indeed other current and developing protocols that permit Layer 2 extension are understood and appreciated to fall within the present teachings for a multi-tenant datacenter with OSI Layer 2 could interconnection.

To summarize, for at least one embodiment the MTDC **100** consists of a plurality of physical client systems **102** in a first datacenter **104**, each physical client system **102** having a set of physical infrastructure resources **106**. A first cloud **108** is also established in the first datacenter **104**. The first cloud **108** is coupled to the physical client systems **102** by OSI Layer 2, the first cloud **108** thereby virtually extending the physical infrastructure resources **106** of each physical client system **102**.

FIG. 2 conceptually illustrates a further embodiment of the present invention wherein multiple MTDC **100** instal-

lations are interconnected. More specifically, in FIG. 2, MTDC **100** is generally shown reproduced at a smaller scale.

An additional installation of multi-tenant datacenters with OSI Layer 2 interconnection is shown as MTDC **200** having a second cloud computing environment, hereinafter second cloud **208** in a second datacenter **204**, also housing at least one client system **202**. The second cloud **208** is established in the second datacenter **204** by one or more physical and/or virtual computer systems **210**. Moreover, with respect to this description it is understood and appreciated that MTDC **100** refers generally to the single multi-tenant datacenter as shown in FIG. 1, however MTDC **100** may also refer to embodiments having multiple distinct datacenters that are interconnected. To the extent possible distinct references, such as MTDC **200** and MTDC **250** are used to help distinguish between specific instances, but in the absence of such distinction a general reference to MTDC **100** may be applied to the collective whole of interconnected datacenters.

As with the client systems **102** of MTDC **100**, each client system **202** of MTDC **200** has a set of physical infrastructure resources **206**. As the client system **202** is coupled to the second cloud **208** by OSI Layer 2, the second cloud **208** virtually extends the physical infrastructure resources of each physical client **202**. For at least one embodiment the coupling of the client systems **202** to the second cloud **208** is performed with a switch **212**.

A third instance of a multi-tenant datacenter with OSI Layer 2 interconnection is also shown as MTDC **250**, and for ease of illustration and discussion is conceptually shown as a cloud. It is understood and appreciated that MTDC **250** comprises substantially the same components and elements of configuration as shown and described with respect to MTDC **100** and MTDC **200**. Additional instances of MTDC may of course also be provided but are not shown for ease of illustration and discussion. As with the use of OSI Layer 2 tags to uniquely identify the interconnections of client systems **102** and the first cloud **108**, OSI Layer 2 tags are used to uniquely identify each cloud, e.g., first cloud **108**, second cloud **208**, and the cloud of MTDC **250**, not shown. Moreover, in at least one embodiment each datacenter, i.e., cloud has its own pre-defined OSI Layer 2 tag or range or OSI Layer 2 tags, these tags provided in the map established with each switch, e.g., switch **116**, **212** in each MTDC, e.g., MTDC **100**, **200**.

With respect to FIG. 2, MTDC **100**, MTDC **200** and MTDC **250** are shown as being interconnected by switches **124**, **220** and **222** which permit OSI Layer 2 interconnection over dedicated lines **224**, **226** and **228**. OSI Layer 2 interconnection of MTDCs is advantageous as each cloud, e.g., first cloud **108** and second cloud **208** of each interconnected MTDC is indistinguishable by the plurality of client systems **102**, **202**.

Moreover, the infrastructure resources of the first cloud **108** can be utilized by clients systems **204** in the second datacenter **204** as if they were part of the first cloud, and vis-a-versa. Indeed the addition of additional MTDCs such as MTDC **250** advantageously provides further infrastructure resources to the overall interconnected cloud environment.

In short the cloud environment itself is advantageously dynamically adjustable as the OSI Layer 2 interconnections between the various physical datacenters permit the entire cloud environment to be structured and arranged as a collective whole. Such dynamic adjustment may advantageously provide greater efficiency in response time to chang-

ing client system demands, upgrades and overall system maintenance, as well as overall transparent reassignment of infrastructure resources as well as other benefits.

In some embodiments due to cost constraints or other factors it may be desirable to use existing network providers to link one or more MTDCs. Such a configuration is shown in FIG. 3, where switches 124, 220 and 222 have been replaced by routers 300, 302 and 304. As shown, dedicated link 226 is still provided between MTDC 100 and MTDC 250, however network provider link 306 operating at ISO Layer 3 is in place between MTDC 100 and MTDC 200. Likewise network provider link 308 operating at ISO Layer 3 is in place between MTDC 250 and MTDC 200.

The introduction of a network provider links 306 and 308 as a means for interconnection between MTDCs is substantially immaterial. The client systems, e.g., clients 102 and 202 are not aware of the network provider links 306 and 308. More specifically, the client systems 102 and 202 are permitted to continue operation and use of the interconnected cloud resources as part of their own respective LANs. Although an IP address may be added to the frame, the addition is performed by the outbound router, e.g., router 300 and removed upon receipt by the inbound router, e.g., router 302—the addition and removal being transparently performed from the perspective of the client systems 102, 202 and the respective systems 110, 210 virtually extending the infrastructure resources.

In general, where multiple clients share space and facility resources the costs per client are generally reduced from what would otherwise be required in the support of a single client. As such, for clients with investments in physical computer resources integration of those resources into MTDC 100 advantageously permits dynamic adaptation of infrastructure as a service in a multi-tenant environment that is not otherwise available.

It is also understood and appreciated that the features and benefits of MTDC 100 alone or interconnected with other MTDCs, e.g., MTDC 200 are not limited to physical client systems 102. For at least one embodiment of MTDC 100, an entirely virtualized client system is established within MTDC 100. For such an embodiment, the virtualized client system enjoys substantially the same advantages of dynamic scalability, permitted overlapping IP ranges, permitted overlapping VLANs and other benefits provided to the physical client systems 102. Should one or more virtual client systems be established in an embodiment consisting of multiple interconnected MTDCs, e.g., at least MTDC 100 and 200 the advantages provided to the virtualized client system are further extended as with the physical client systems 102 and 202.

FIG. 4 conceptually illustrates a high level flow diagram depicting at least one method 400 for a multi-tenant datacenter, e.g., MTDC 100, and FIG. 5 conceptually illustrates a more refined method 500 for a multi-tenant datacenter, e.g., MTDC 100 or interconnected plurality of MTDCs. It will be understood and appreciated that the described methods need not be performed in the order in which it is herein described, but that this description is merely exemplary of one method for providing MTDC 100.

At a high level, method 400 may be summarized and understood as follows. For the illustrated example, method 400 commences with establishing a first cloud 108 in a first datacenter 104, block 402 and see FIG. 1. At least one physical client system 102 is then also located within the first datacenter 108, block 404. As shown and described above with respect to FIG. 1, each physical client system 102 has a set of physical infrastructure resources 106.

The physical client 102 and first cloud 108 are then coupled by OSI Layer 2, block 406. As shown in comparison of FIG. 1 to FIGS. 2 and 3, there can be one instance of MTDC 100 or a plurality of them interconnected. Method 400 addresses this possibility with decision 408. For a first embodiment consisting of a single instance of MTDC 100 (Multiple Clouds=No), method 400 moves to employing OSI Layer 2 tagging to uniquely identify all data frames, block 410.

For at least one embodiment, the OSI Layer 2 tagging is QinQ tagging, with the first Q tag identifying the host, block 412, and the second Q tag identifying the customer, block 414. In varying alternative embodiments additional OSI Layer 2 tags may also be employed such as for example VPLS and MPLS tags. Again, as noted above, the use of Q tags, QinQ tags, MPLS tags, VPLS tags and combinations thereof are exemplary of Layer 2 tags permitting Layer 2 extension, and are not

Moreover, the use of Layer 2 tags selected from the group consisting of, but not limited to, Q tags, QinQ tags, MPLS tags, VPLS tags, are to be understood and appreciated as options for one or more specific embodiments, and not as limitations. Indeed other current and developing protocols that permit Layer 2 extension are understood and appreciated to fall within the present teachings for Layer 2 tagging to uniquely identify all data frames.

The OSI Layer 2 tagging permits the dynamic extension of at least one physical client system's physical infrastructure resources into the cloud computing environment, block 416.

With respect to decision 408 and the evaluation of multiple clouds, for at least a second embodiment consisting of multiple instances of MTDC, e.g., at least MTDC 100 and MTDC 200 (Multiple Clouds=Yes), method 400 moves to establishing at least one second cloud 208 in at least one second datacenter 204, block 418 and see FIG. 2.

As noted above, the first cloud 108 is coupled to the second cloud 208 by OSI Layer 2, block 420. Moreover, the methodology of mapping MAC addresses and Q tags as employed for the OSI Layer 2 coupling of client systems 102 to the first cloud 108 is extrapolated and applied to couple the first cloud 108 and the second cloud 208. As shown in FIG. 2, for at least one embodiment this cloud to cloud coupling of multiple MTDCs is entirely OSI Layer 2.

However, for at least one optional environment as shown in FIG. 3 long haul network provider links may be employed. For such an embodiment, transparent Layer 3 transformation is performed merely for the long haul component of connection between physical datacenters, block 422. The Layer 3 and IP component is not apparent to the client systems or the cloud supporting systems. With the resources virtually extended as indicated by block 416, method 400 continues as long as desired, decision 424.

Moreover, coupling the client systems 102 to the first cloud 108, as indicated by block 406 permits the clients and their associated cloud resources to appear as being on the same LAN, dotted oval 426. In addition, the OSI Layer 2 tagging, such as provided by the QinQ tagging of blocks 412 and 414 for the dynamic extension of the client resources into the cloud as in block 416 advantageously permits multiple clients to have overlapping IP and or VLAN settings without interference, dotted oval 428.

To summarize, for at least one embodiment a method 400 of providing MTDC 100 consists of establishing within a first datacenter 104 a first cloud 108. At least one physical client system 102 is also located within the first datacenter 104, each physical client system 102 having a set of physical

infrastructure resources **106**. The method **400** continues by coupling the at least one physical client system **102** to the first cloud **108** by OSI Layer 2, the OSI Layer 2 coupling thereby virtually extending the physical infrastructure resources **106** of each physical client system **102**.

An embodiment of a method **400** for providing MTDC **100** may also be summarized as establishing within a first datacenter **104** a first cloud **108**, and locating a plurality of physical client systems **102** in the first datacenter **108**, each physical client system **102** having a set of physical infrastructure resources. The method continues by uniquely identifying data traffic as between each client system **102** and the first cloud **108** by a plurality of OSI Layer 2 tags permitting unique identification for each client system **102** of at least one host and a customer.

FIG. 5 conceptually illustrates a more refined method **500** for a multi-tenant datacenter further illustrating the use of additional OSI Layer 2 tags with respect to resources in different cloud computing environments **108**.

Method **500** commences with establishing a first cloud **108** in a first datacenter **104**, locating at least one physical client system **102** within the first datacenter **104** and coupling the client system **102** to the first cloud **108**, block **502**.

Next, a second cloud **208** in a second datacenter **204** is established, at least one physical client system **202** is located within the second datacenter **204** and the client system **202** and second cloud **208** are coupled, block **504**. MTDC **100** and MTDC **200** are then coupled, block **506**.

For the example method **500**, next is a query to determine if a client system has multiple VLANs, decision **508**. If the answer is NO, the method **500** proceeds to apply OSI Layer 2 tags for each client connection for unique identification of all data frames, block **510**. For at least one embodiment, the OSI Layer 2 tagging is QinQ tagging, with the first Q tag identifying the host, block **512**, and the second Q tag identifying the customer, block **514**. In varying alternative embodiments additional or alternative OSI Layer 2 tags may be employed, such as for example VPLS and MPLS tags.

Where indeed there are multiple VLANs, an answer of Yes for decision **508**, the method **500** proceeds to apply Level 2 tags to uniquely identify each VLAN for each client system **102**. For at least one embodiment this OSI Layer 2 tagging is QinQ tagging. Moreover, method **500** proceeds to select a VLAN, block **516**, apply the first Q tag identifying the host, block **518** and the second Q tag identifying the customer, block **520**. If there are more VLANs remaining, decision **522**, the next VLAN is selected, block **524** and the process repeats until all VLANs have been uniquely tagged.

For proper delivery of the frame, the map of the pre-defined OSI Layer 2 tags is consulted to determine the location of the resource. With respect to FIG. 1 and the above description, it is understood and appreciated that the map is an element of switch **116**. With respect to the multi MTDC configuration shown in FIGS. 2 and 3, each MTDC instance has a switch, e.g., switch **212** of MTDC **200**, which also a map table for the pre-defined OSI Layer 2 tags.

FIGS. 6, 7 and 8 provide conceptual examples of this OSI Layer 2 tagging for the unique identification each frame and are provided to further assist in appreciating the method of providing a multi-tenant datacenter.

More specifically, FIG. 6 illustrates a frame as between C1, client system **102A** (having origin MAC address 57:89:6f:88:9d:c7), and physical cloud system **110A** (having destination MAC address 28:08:80:52:17:20) and a payload **608** "Happy". For ease of illustration and discussion, the OSI Layer 2 tags as employed have been illustrated conceptually in an easy to read and understand manner. Client

system **102A** has been assigned A series tags, and an appropriate Tag1 **612** and Tag2 **614** demonstrate this. For the sake of example, the IP ranges for the LAN of client system **102A** may be 10.20.30.0-50.

FIG. 7 illustrates two frames, **700** and **750**. The first, illustrates a frame **700** as between C2, client system **102B** (having origin MAC address 04:7A:9e:a1:a3:41), and physical cloud system **110B** (having destination MAC address 6e:25:47:1f:9a:97). Frame **700** has the same basic structure as frame **600**, a preamble **702**, destination MAC **704**, origin Mac **706**, a payload **708** and a gap sequence **710**. For frame **700** the payload **708** is "Grumpy".

Client system **102B** has been assigned B series tags as demonstrated by Tag1 **712** and Tag2 **714**. For the sake of example, the IP ranges for the LAN of client system **102B** may be 10.20.30.20-80. As such, clearly there is the possibility for overlapping IP addresses with client system **102A** and client system **102B**, those between 10.20.30.20, and 10.20.30.50. However, as neither frame **600** nor frame **700** includes a tag for representation of an IP address as specified by either the origin or the destination, any overlapping of IP addresses is of no consequence and will not interfere with the delivery of the frames.

As noted above, in at least one embodiment, the first cloud **108** comprises at least one virtual machine which is structured and arranged to provide infrastructure services to at least one client system **102**. FIG. 7 also illustrates a frame **750** as between C2, client system **102B** (having origin MAC address 04:7A:9e:a1:a3:41), and virtual cloud system **110C** (having destination MAC address 8a:02:28:11:2a:01) and a payload **708** "Sneezy".

As noted with respect to frame **700**, client system **102B** has been assigned B series tags. As such for this example Tag1 **712'** for the host in frame **750** is the same as Tag1 **712** in frame **700**. However, the customer in this example is different so Tag2 **714'** is different. Moreover, for the purposes of tagging frame **750** the nature of the destination system as being virtual is substantially irrelevant.

Returning to method **500** in FIG. 5, a query is performed to determine if the requested resource is within the current cloud, decision **526**. For the example frames **600**, **700** and **750** the answer is "Yes" as the client systems, respectively **102A**, **102B** and **102C** are all within the first datacenter **104**, and each frame **600**, **700** and **750** indicates the destination system is within the first cloud **108**.

As such, switch **116** directs each frame from the received port **120** to the proper outbound port **122** to which is coupled the desired resource. It is also understood and appreciated that switch **116** will remove the OSI Layer 2 tags that are not expected, block **528**. More specifically, if the client system is employing a VLAN and has employed use of a Q Tag, that Q Tag will remain, but the additional OSI Layer 2 tags applied by MTDC **100** are removed at the time of delivery, such that the physical or virtual resource in the cloud receives the frame in expected form, block **530**.

FIG. 8 illustrates a frame as between Cr, client system **202** (having origin MAC address f3:98:19:ab:55:b4), and physical cloud system **110D** (having destination MAC address 09:19:20:07:05). It is also appreciated that client system **202** is in second datacenter **204** and physical cloud system **110D** is in first cloud **108**. Frame **800** has the same basic structure as frame **600**, a preamble **802**, destination MAC **804**, origin Mac **806**, a payload **808** and a gap sequence **810**. For frame **800** the payload **808** is "Dopey".

Client system **202** has been assigned C series tags as demonstrated by Tag1 **812**, Tag2 **814** and Tag3 **816**. Tag3 **816** is identifying the datacenter having the resource, spe-

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cifically the first datacenter **108**. For at least one embodiment the additional OSI Layer 2 tag identifying the datacenter, e.g., Tag3 **816** is a VPLS tag.

Returning to decision **526**, in the event that it is determined that the resource is not in the current cloud, as in the case of frame **800**, method **500** proceeds to add appropriate OSI Layer 2 tagging to identify the datacenter containing the resource, block **532**. The frame, e.g., frame **800**, is then directed to the proper cloud, block **534**.

With respect to FIG. 2, it is appreciated that frame **800** is provided from switch **212**, to switch **222**, to switch **220**, and finally to switch **116**, and that that switch **116** will remove the OSI Layer 2 tags that are not expected, block **528**.

Again as noted above, in at least one embodiment existing network provider connections may be used to interconnect different datacenters. In FIG. 8 frame **800'** represents the additional OSI Layer 2 tagging that may be applied in at least one embodiment to enable use of the existing network connections as shown in FIG. 3. In addition to Tag3 identifying the datacenter, Tag4 **818** has been added to identify the long haul network IP. For at least one embodiment the additional OSI Layer 2 tag identifying the network IP, e.g., Tag4 **818** is a MPLS tag.

Moreover, for this optional use of an existing long haul interconnection, method **500** adds a fourth OSI Layer 2 tag to identify the network IP, block **536**, and the frame is transferred from one datacenter to another. In at least one embodiment the addition of this fourth OSI Layer 2 tag is performed by router, e.g., router **302** in FIG. 3, and then removed by router **300**, such that the layer 3 transfer is entirely transparent, block **538**.

Once again it will be appreciated that the use of Layer 2 tags selected from the group consisting of, but not limited to, Q tags, QinQ tags, MPLS tags, VPLS tags, is understood as exemplary for one or more embodiments, and not as limitations. Indeed other current and developing protocols that permit Layer 2 extension are understood and appreciated to fall within the present teachings for Layer 2 tagging.

With the frame delivered, the method **500** moves to decision **540** and the query of whether to continue or not. When the system remains active, MTDC **100** awaits new data, block **542**, which may be in the form of a new client VLAN being added, a new frame from a client system, or a new frame from an extended resource within the cloud. Indeed, although the above description has been presented for the progression of a frame from a client system to a resource within the cloud, it is understood and appreciated that generally the same process is performed to transfer a frame from an extended resource within the cloud to an associated client system. Moreover, with respect to frame **600**, interchanging the origin MAC address and **604** and the destination MAC address **606** would provide a frame for transfer from system **110A** in the first cloud **108** to client system **102A**.

To summarize, for at least one embodiment, a method of providing MTDC **100** consists of establishing within a first datacenter **104** a first cloud **108** having first physical resources and first virtual resources and establishing within a second datacenter **204** a second cloud **208** having second physical resources and second virtual resources. The first cloud **108** and the second cloud **208** are coupled together by OSI Layer 2.

Further, for at least one embodiment, this method of providing MTDC **100** is enhanced by disposing a plurality of physical client systems, e.g., **102** and **202** in one or both of the first datacenter **104** and the second datacenter **204**, each physical client system having a set of physical infra-

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structure resources **106**, **206**. The method continues by coupling each physical client system, **102**, **202** to the coupled first and second clouds **108**, **208** by OSI Layer 2, the coupled cloud computing environment thereby virtually extending the physical infrastructure resources **106**, **206** of each physical client system **102**, **202**.

With respect to the above description of MTDC **100**, multiple instances of MTDCs, and methods **400** and **500** it is understood and appreciated that the method may be rendered in a variety of different forms of code and instruction as may be used for different computer systems and environments. To expand upon the initial suggestion of client systems **102** and cloud systems **110**, FIG. 9 is a high level block diagram of an exemplary computer system **900**. Computer system **900** has a case **902**, enclosing a main board **904**. The main board **904** has a system bus **906**, connection ports **908**, a processing unit, such as Central Processing Unit (CPU) **910** with at least one macroprocessor (not shown) and a memory storage device, such as main memory **912**, hard drive **914** and CD/DVD ROM drive **916**.

Memory bus **918** couples main memory **912** to the CPU **910**. A system bus **906** couples the hard disc drive **914**, CD/DVD ROM drive **916** and connection ports **908** to the CPU **910**. Multiple input devices may be provided, such as, for example, a mouse **920** and keyboard **922**. Multiple output devices may also be provided, such as, for example, a video monitor **924** and a printer (not shown). As computer system **900** is intended to be interconnected with other computer systems in the MTDC **100** a combined input/output device such as at least one network interface card, or NIC **926** is also provided.

Computer system **900** may be a commercially available system, such as a desktop workstation unit provided by IBM, Dell Computers, Gateway, Apple, or other computer system provider. Computer system **900** may also be a networked computer system, wherein memory storage components such as hard drive **914**, additional CPUs **910** and output devices such as printers are provided by physically separate computer systems commonly connected together in the network. Those skilled in the art will understand and appreciate that the physical composition of components and component interconnections are comprised by the computer system **900**, and select a computer system **900** suitable for one or more of the computer systems incorporated in the formation and operation of MTDC **100**.

When computer system **900** is activated, preferably an operating system **926** will load into main memory **912** as part of the boot strap startup sequence and ready the computer system **900** for operation. At the simplest level, and in the most general sense, the tasks of an operating system fall into specific categories, such as, process management, device management (including application and user interface management) and memory management, for example. The form of the computer-readable medium **928** and language of the program **930** are understood to be appropriate for and functionally cooperate with the computer system **900**.

Moreover, variations of computer system **900** may be adapted to provide the physical elements of one or more components comprising each client system **102**, the one or more components comprising the system **110** supporting the cloud environment, the switches, routers and such other components as may be desired and appropriate for MTDC **100**.

It is to be understood that changes may be made in the above methods, systems and structures without departing from the scope hereof. It should thus be noted that the matter



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contained in the above description and/or shown in the accompanying drawings should be interpreted as illustrative and not in a limiting sense. The following claims are intended to cover all generic and specific features described herein, as well as all statements of the scope of the present method, system and structure, which, as a matter of language, might be said to fall therebetween.

What is claimed is:

1. A multi-tenant datacenter having Layer 2 architecture to maintain original client Layer 2 configurations without reconfiguration or virtualization of client systems and permit software defined networking, comprising:

a plurality of physical client systems in a first datacenter each physical client system having a set of physical infrastructure resources and an original Layer 2 configuration; and

a first cloud computing environment established in the first datacenter having Layer 2 architecture to maintain the original client Layer 2 configurations, and coupled to the physical client systems by OSI Layer 2 for the transfer of data frames prior to an OSI Layer 3 connection, each frame having a plurality of OSI Layer 2 tags applied prior to a Layer 3 activity permitting at least two client systems to have overlapping VLANs, the first cloud computing environment thereby virtually extending the physical infrastructure resources of each physical client system, wherein each client system maintains client's original Layer 2 configuration without reconfiguration or virtualization, and may self direct software defined networking.

2. The multi-tenant datacenter of claim 1, further including at least one OSI Layer 2 tag for identification of a datacenter.

3. The multi-tenant datacenter of claim 1, further including at least one OSI Layer 2 tag for identification of a network IP address for a remote datacenter.

4. The multi-tenant datacenter of claim 1, wherein the OSI Layer 2 tags are selected from the group consisting of: QinQ tags, MPLS tags, and VPLS tags.

5. The multi-tenant datacenter of claim 1, wherein the OSI Layer 2 tags permit at least two client systems to have overlapping IP address ranges.

6. The multi-tenant datacenter of claim 1, wherein at least one second cloud computing environment established in at least one second datacenter is coupled to the first datacenter by OSI Layer 2.

7. The multi-tenant datacenter of claim 6, wherein the second cloud computing environment is indistinguishable from the first cloud computing environment by the plurality of physical client systems.

8. The multi-tenant datacenter of claim 6, further including at least one entirely virtualized client system within the combined first and second cloud computing environment.

9. The multi-tenant datacenter of claim 6, wherein a plurality of second physical client systems each having a set of physical infrastructure resources are disposed in the second datacenter and coupled to the second cloud computing environment by OSI Layer 2, at least one second physical client systems further utilizing a resource of the first cloud computing environment in the first datacenter.

10. A method for providing a multi-tenant datacenter having Layer 2 architecture to maintain original client Layer 2 configurations without reconfiguration or virtualization of client systems and permit software defined networking, comprising:

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establishing within a first datacenter a first cloud computing environment having Layer 2 architecture to maintain a plurality of original client Layer 2 configurations;

locating at least one physical client system in the first datacenter, each physical client system having a set of physical infrastructure resources and an original Layer 2 configuration; and

coupling the at least one physical client system to the first cloud computing environment by OSI Layer 2 for the transfer of data frames prior to an OSI Layer 3 connection, each frame having a plurality of OSI Layer 2 applied prior to a Layer 3 activity tags permitting at least two client systems to have overlapping VLANs at Layer 3 as frame transmission is distinct from packet transmission, the OSI Layer 2 coupling virtually extending the physical infrastructure resources of each physical client system, wherein each client system maintains client's original Layer 2 configuration without reconfiguration or virtualization, and may self direct software defined networking.

11. The method for providing a multi-tenant of claim 10, wherein at least one second cloud computing environment established in at least one second datacenter is coupled to the first datacenter by OSI Layer 2.

12. The method for providing a multi-tenant of claim 10, wherein the second cloud computing environment is indistinguishable from the first cloud computing environment.

13. The method for providing a multi-tenant of claim 10, further including at least one entirely virtualized client system within the combined first and second cloud computing environment.

14. The method for providing a multi-tenant of claim 10, wherein a plurality of second physical client systems each having a set of physical infrastructure resources are also established in the second datacenter and coupled to the second cloud computing environment by OSI Layer 2, at least one second physical client systems further utilizing a resource of the first cloud computing environment in the first datacenter.

15. The method for providing a multi-tenant of claim 10, wherein the coupling of the at least one physical client system and the first cloud computing environment by frames permits unique identification for each client system of at least a host and a customer.

16. The method for providing a multi-tenant of claim 10, further including at least one OSI Layer 2 tag for identification of a datacenter.

17. The method for providing a multi-tenant of claim 10, further including at least one OSI Layer 2 tag for identification of a network IP address for a remote datacenter.

18. The method for providing a multi-tenant of claim 10, wherein the OSI Layer 2 tags are selected from the group consisting of: QinQ tags, MPLS tags, and VPLS tags.

19. The method for providing a multi-tenant of claim 10, wherein the OSI Layer 2 tags permit at least two client systems to have overlapping IP address ranges.

20. The method for providing a multi-tenant of claim 10, wherein each frame provided by a client system does not contain an IP address for a resource within the first cloud computing environment.

21. A method for providing a multi-tenant datacenter having Layer 2 architecture to maintain original client Layer 2 configurations without reconfiguration or virtualization of client systems and permit software defined networking, comprising:

establishing within a first datacenter a first cloud computing environment having Layer 2 architecture to maintain a plurality of original client Layer 2 configurations;

locating a plurality of physical client systems in the first datacenter, each physical client system having a set of physical infrastructure resources and an original Layer 2 configuration; and

uniquely identifying Layer 2 data traffic distinct from Layer 3 as between each client system and the first cloud computing environment for the transfer of data frames distinct from the transfer of packets of a network layer, each frame having a plurality of OSI Layer 2 tags as unique identifiers permitting unique identification for each client system of at least one host and a customer, the OSI Layer 2 tags permitting at least two client systems to have overlapping VLANs at Layer 3 as frame transmission is distinct from packet transmission, and wherein each client system maintains client's original Layer 2 configuration without reconfiguration or virtualization, and may self direct software defined networking.

22. The method for providing a multi-tenant of claim 21, wherein the first cloud computing environment thereby virtually extends the physical infrastructure resources of each physical client system.

23. The method for providing a multi-tenant of claim 21, further including unique identification of a datacenter.

24. The method for providing a multi-tenant of claim 21, further including unique identification of a network IP address for a remote datacenter.

25. The method for providing a multi-tenant of claim 21, wherein the OSI Layer 2 tags are selected from the group consisting of: QinQ tags, MPLS tags, and VPLS tags.

26. The method for providing a multi-tenant of claim 21, wherein the unique identifiers permit at least two client systems to have overlapping IP address ranges.

27. A method for providing a multi-tenant datacenter having Layer 2 architecture to maintain original client Layer 2 configurations without reconfiguration or virtualization of client systems and permit software defined networking, comprising:

establishing within a first datacenter a first cloud computing environment having Layer 2 architecture to maintain a plurality of original client Layer 2 configurations,

the first datacenter having first physical resources and first virtual resources;

establishing within a second datacenter a second cloud computing environment having Layer 2 architecture to maintain a plurality of original client Layer 2 configurations, the second datacenter having second physical resources and second virtual resources; and

coupling the first cloud computing environment to the second cloud computing environment by OSI Layer 2 for the transfer of data frames distinct from OSI Layer 3 network layer traffic, each frame having a plurality of OSI Layer 2 tags permitting at least two systems utilizing the coupled first datacenter and second data center to have overlapping VLANs at Layer 3 as frame transmission is distinct from packet transmission and maintains each system's original Layer 2 configuration without reconfiguration or virtualization.

28. The method for providing a multi-tenant of claim 27, further comprising:

disposing a plurality of physical client systems in one or both of the first datacenter and the second datacenter, each physical client system having a set of physical infrastructure resources; and

coupling each physical client system to the coupled first and second cloud computing environment by OSI Layer 2 for the transfer of data frames, each frame having a plurality of OSI Layer 2 tags, the coupled cloud computing environment thereby virtually extending the physical infrastructure resources of each physical client system, wherein each client system maintains client's original Layer 2 configuration and may self direct software defined networking.

29. The method for providing a multi-tenant of claim 28, wherein the OSI Layer 2 tags are selected from the group consisting of: QinQ tags, MPLS tags, and VPLS tags.

30. The method for providing a multi-tenant of claim 28, wherein the OSI Layer 2 tags permit at least two client systems to have overlapping IP address ranges.

31. The method for providing a multi-tenant of claim 28, wherein the OSI Layer 2 tags permit at least two client systems to have overlapping VLANs.

\* \* \* \* \*

UNITED STATES PATENT AND TRADEMARK OFFICE  
**CERTIFICATE OF CORRECTION**

PATENT NO. : 9,571,301 B2  
APPLICATION NO. : 13/356555  
DATED : February 14, 2017  
INVENTOR(S) : Norris et al.

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the Title Page

Item (73), Assignee: delete "The Faction Group, LLC" and replace it with --The Faction Group LLC--.

In the Claims

Column 15, Line 63-Column 16, Line 21, (approx.), should read:

10. A method for providing a multi-tenant datacenter having Layer 2 architecture to maintain original client Layer 2 configurations without reconfiguration or virtualization of client systems and permit software defined networking, comprising:  
establishing within a first datacenter a first cloud computing environment having Layer 2 architecture to maintain a plurality of original client Layer 2 configurations;  
locating at least one physical client system in the first datacenter, each physical client system having a set of physical infrastructure resources and an original Layer 2 configuration; and  
coupling the at least one physical client system to the first cloud computing environment by OSI Layer 2 for the transfer of data frames prior to an OSI Layer 3 connection, each frame having a plurality of OSI Layer 2 tags applied prior to a Layer 3 activity permitting at least two client systems to have overlapping VLANs at Layer 3 as frame transmission is distinct from packet transmission, the OSI Layer 2 coupling virtually extending the physical infrastructure resources of each physical client system, wherein each client system maintains client's original Layer 2 configuration without reconfiguration or virtualization, and may self direct software defined networking.



Signed and Sealed this  
Tenth Day of July, 2018

*Andrei Iancu*

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Director of the United States Patent and Trademark Office