



US010382229B2

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

(10) **Patent No.:** **US 10,382,229 B2**
(45) **Date of Patent:** ***Aug. 13, 2019**

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

(71) Applicant: **The Faction Group LLC**, Denver, CO
(US)

(72) Inventors: **Luke Matthew Norris**, Denver, CO
(US); **Hooker Ashley Heggestad**,
Lafayette, CO (US)

(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 21 days.

This patent is subject to a terminal dis-
claimer.

(21) Appl. No.: **15/424,651**

(22) Filed: **Feb. 3, 2017**

(65) **Prior Publication Data**

US 2017/0149896 A1 May 25, 2017

Related U.S. Application Data

(63) Continuation of application No. 14/621,320, filed on
Feb. 12, 2015, now Pat. No. 9,621,374, which is a
(Continued)

(51) **Int. Cl.**
H04L 12/46 (2006.01)
H04L 29/08 (2006.01)
H04L 12/721 (2013.01)

(52) **U.S. Cl.**
CPC **H04L 12/4666** (2013.01); **H04L 12/465**
(2013.01); **H04L 12/4633** (2013.01);
(Continued)

(58) **Field of Classification Search**

CPC H04W 72/0453; H04W 72/042; H04W
72/0446; H04W 72/1257; H04W 76/02;
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

2011/0022721 A1* 1/2011 Diab H04L 69/08
709/233

2011/0075667 A1 3/2011 Li et al.
(Continued)

OTHER PUBLICATIONS

PCT International Search Report for International Application PCT/
US2013/021662, search report dated Apr. 29, 2013 (Apr. 28, 2013).
(Continued)

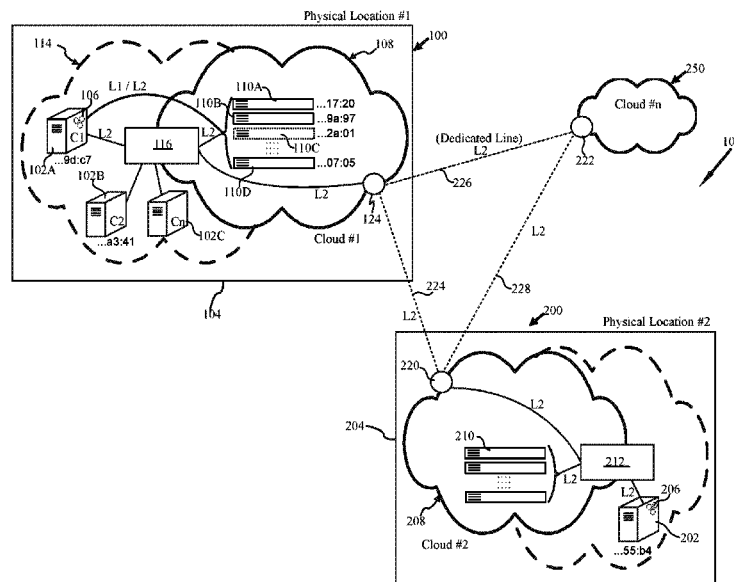
Primary Examiner — Hardikkumar D Patel

(74) *Attorney, Agent, or Firm* — Daniel W. Roberts; Law
Offices of Daniel W. Roberts, LLC

(57) **ABSTRACT**

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

44 Claims, 8 Drawing Sheets



Related U.S. Application Data

continuation of application No. 13/356,555, filed on Jan. 23, 2012, now Pat. No. 9,571,301.

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

CPC *H04L 12/4641* (2013.01); *H04L 45/66* (2013.01); *H04L 67/10* (2013.01); *H04L 67/1097* (2013.01); *H04L 69/324* (2013.01); *H04L 2212/00* (2013.01)

(58) **Field of Classification Search**

CPC . H04W 36/18; H04W 72/1278; H04W 72/04; H04W 40/22; H04L 5/0005; H04L 5/14; H04L 5/26; H04L 12/4666; H04L 12/4633; H04L 12/4641; H04L 12/465; H04L 45/66; H04L 67/10; H04L 67/1097; H04L 69/324; H04L 1/1854; H04L 1/1861; H04L 5/0053; H04L 2001/0097; H04L 5/001; H04L 1/1812; H04L 5/0055; H04L 2001/0092; H04L 5/006; H04L 5/1469; H04B 7/14; H04B 7/155; H04J 3/16; H04J 3/1694

See application file for complete search history.

(56)

References Cited

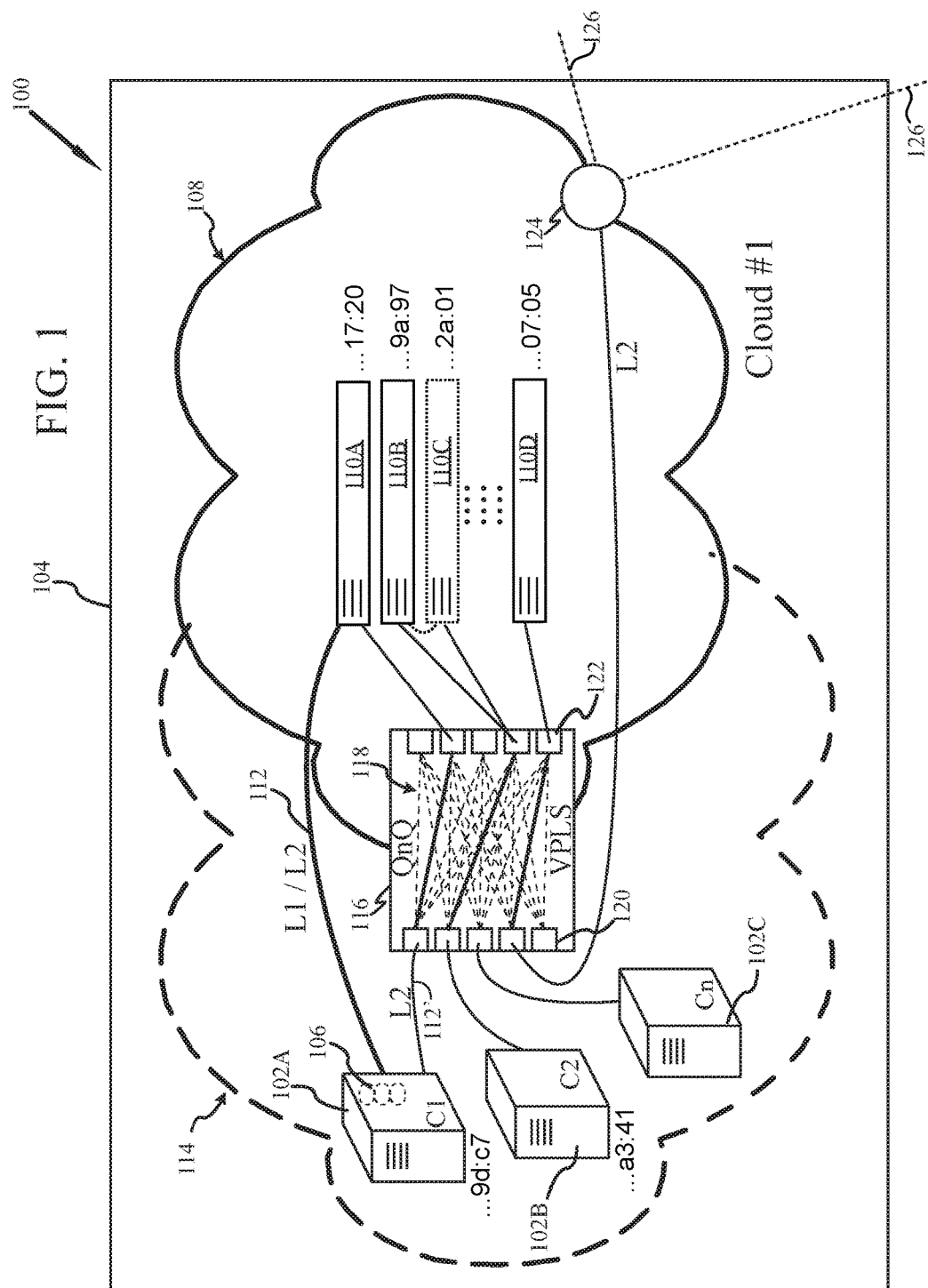
U.S. PATENT DOCUMENTS

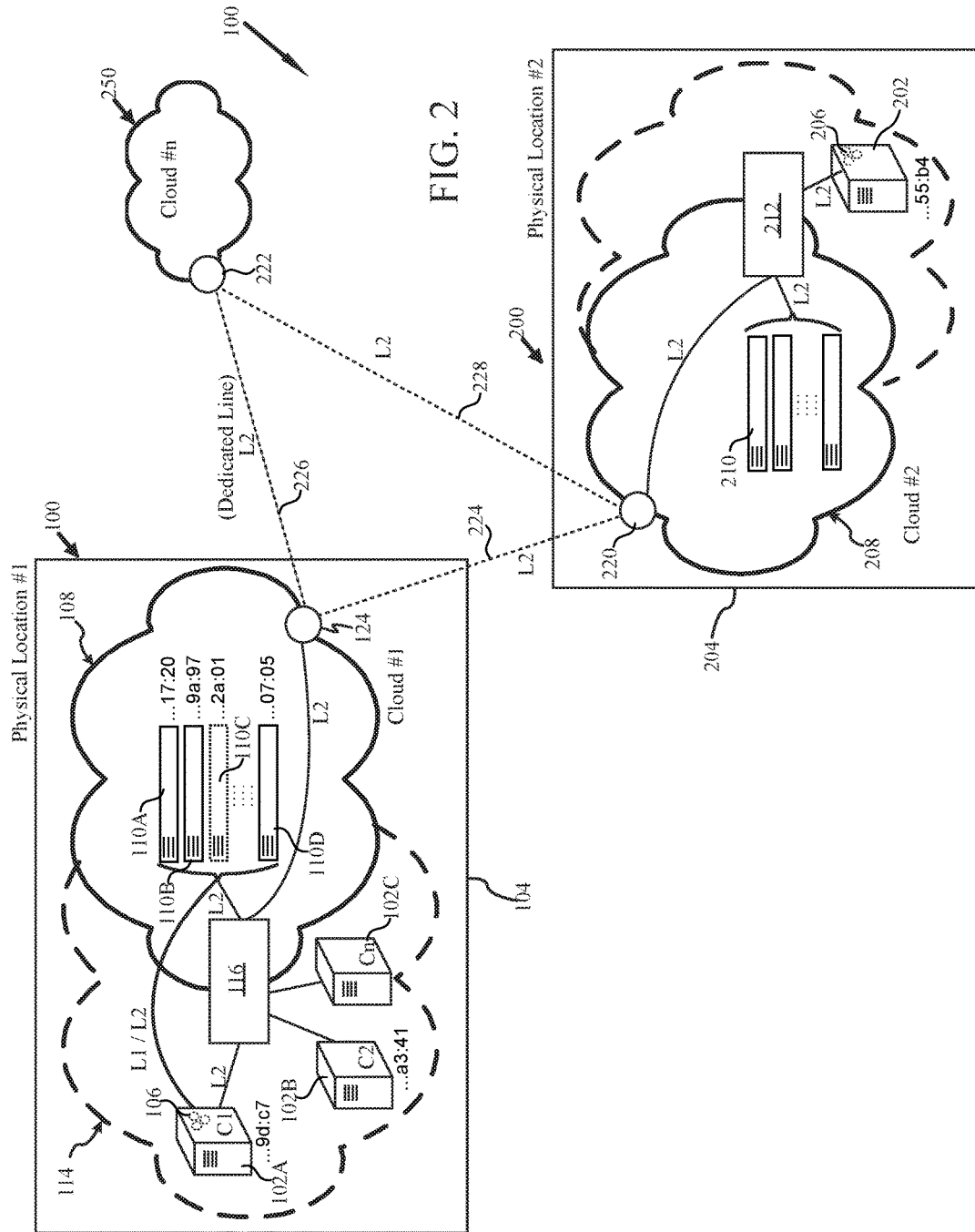
2011/0090911	A1*	4/2011	Hao	H04L 12/4633 370/395.53
2012/0020206	A1	1/2012	Busi et al.	
2012/0233668	A1	9/2012	Leafe et al.	
2012/0281706	A1	11/2012	Agarwal et al.	
2013/0107887	A1	5/2013	Pearson et al.	
2013/0124750	A1	5/2013	Anumal et al.	
2013/0346583	A1*	12/2013	Low	H04L 12/4641 709/223
2014/0115584	A1	4/2014	Mudigonda et al.	

OTHER PUBLICATIONS

PCT International Search Report for International Application PCT/US2013/021662, search report dated Sep. 30, 2013 (Sep. 30, 2013).
 Radia Perlman Intel Labs Dinesh Dutt CISCO Systems Donald Eastlake 3rd Stellar Switches Mar. 7, 2010.
 Carrier Ethernet: The native approach Howard Gree, Sylvain Monette, Jonathan Olsson, Panagiotis Salsidis and Attila Takács, pp. 84-89.

* cited by examiner





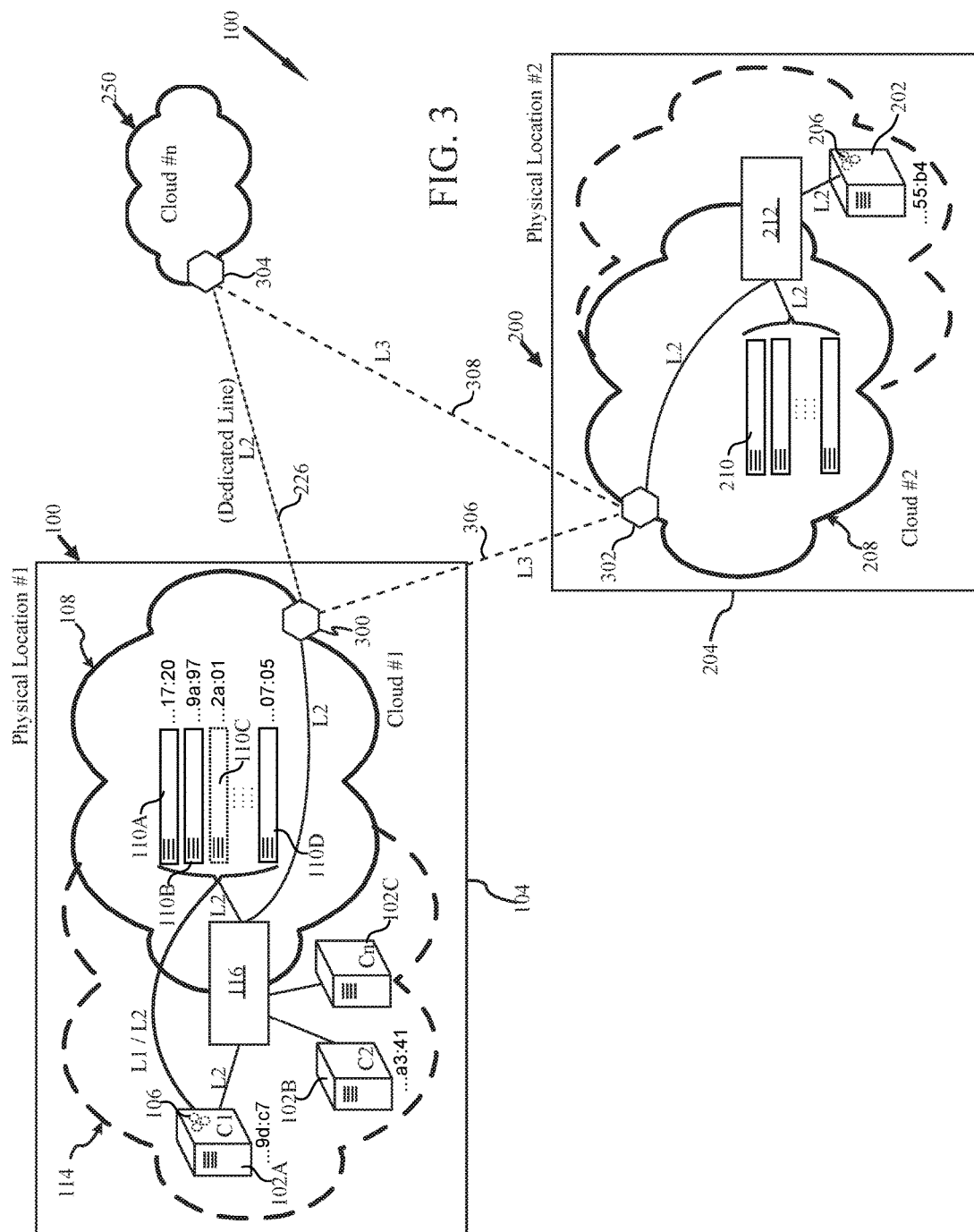
3
G
L
L

FIG. 4

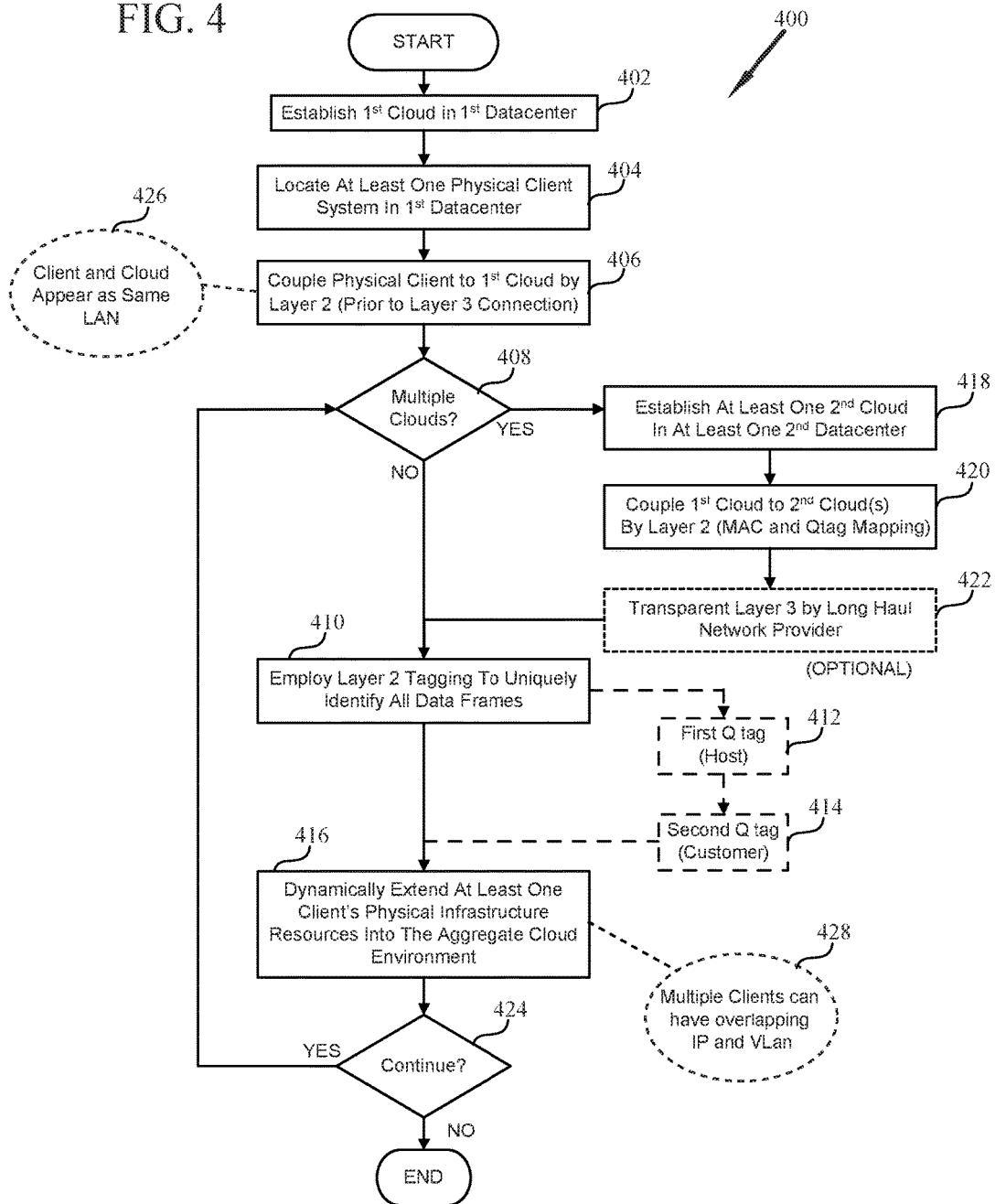


FIG. 5

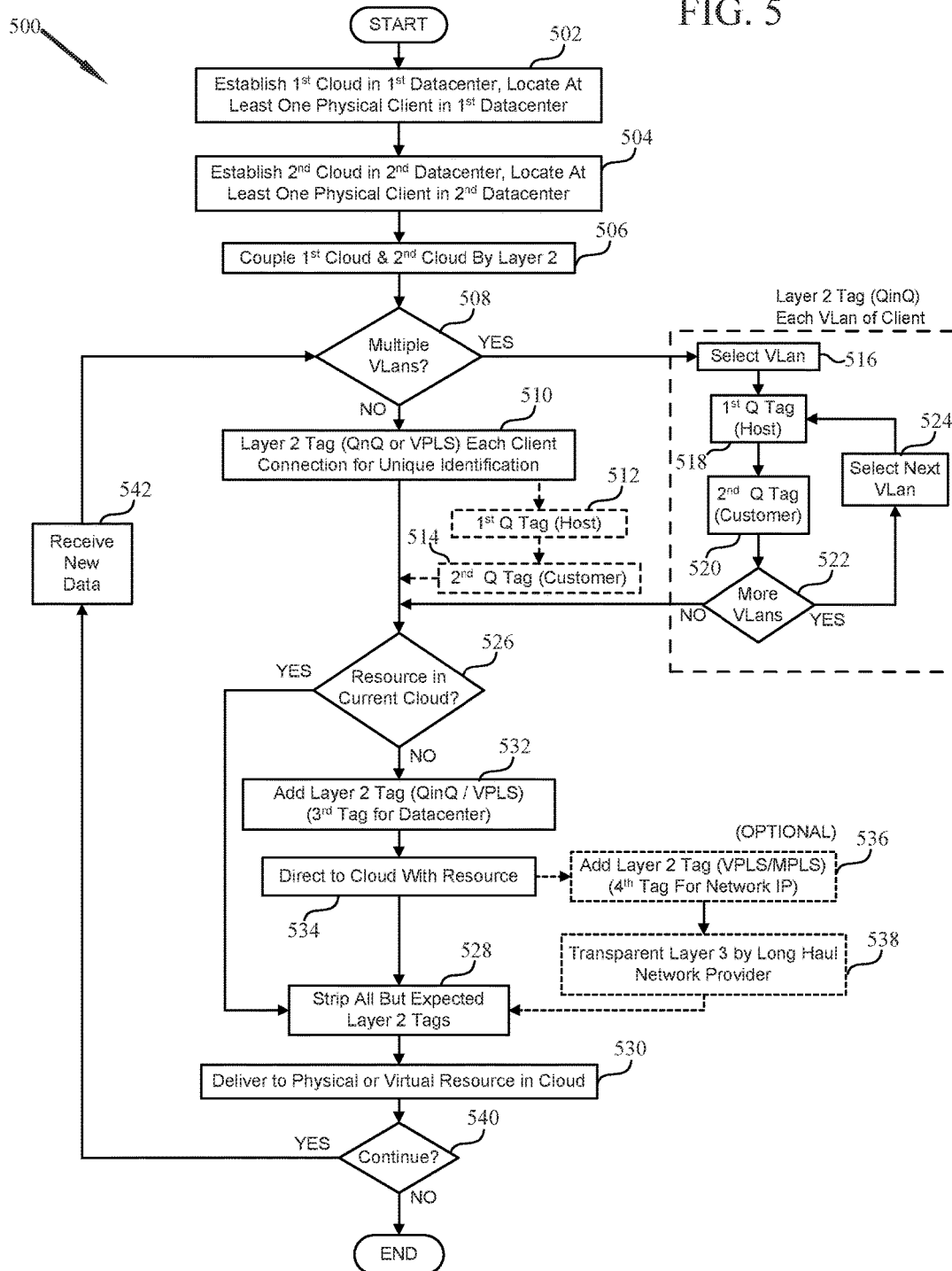


FIG. 6

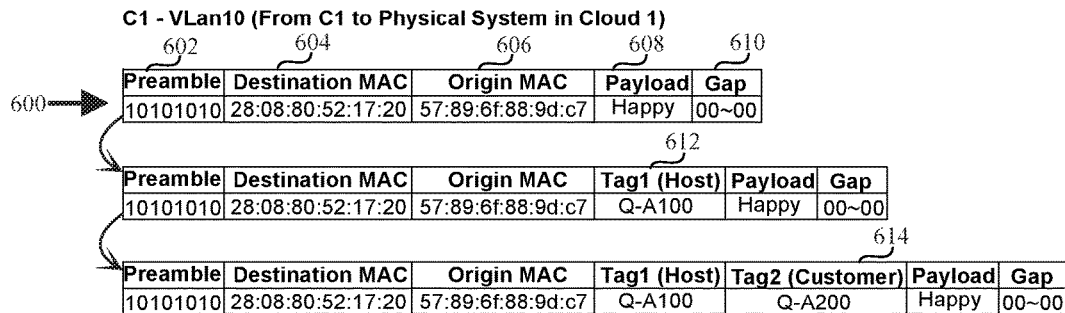


FIG. 7

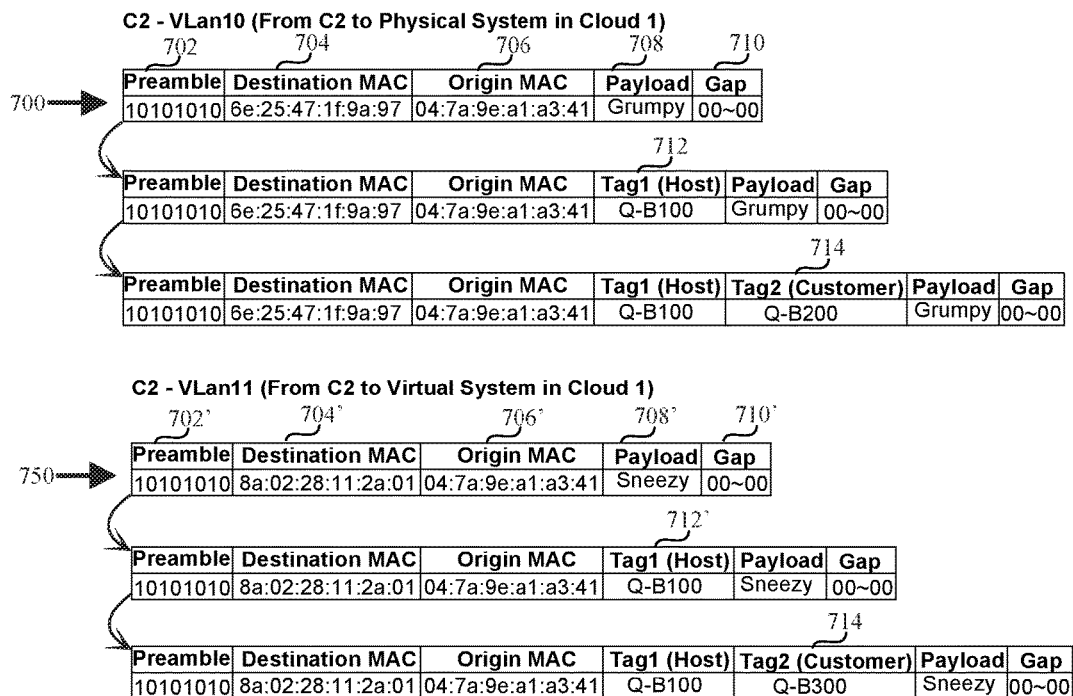


FIG. 8

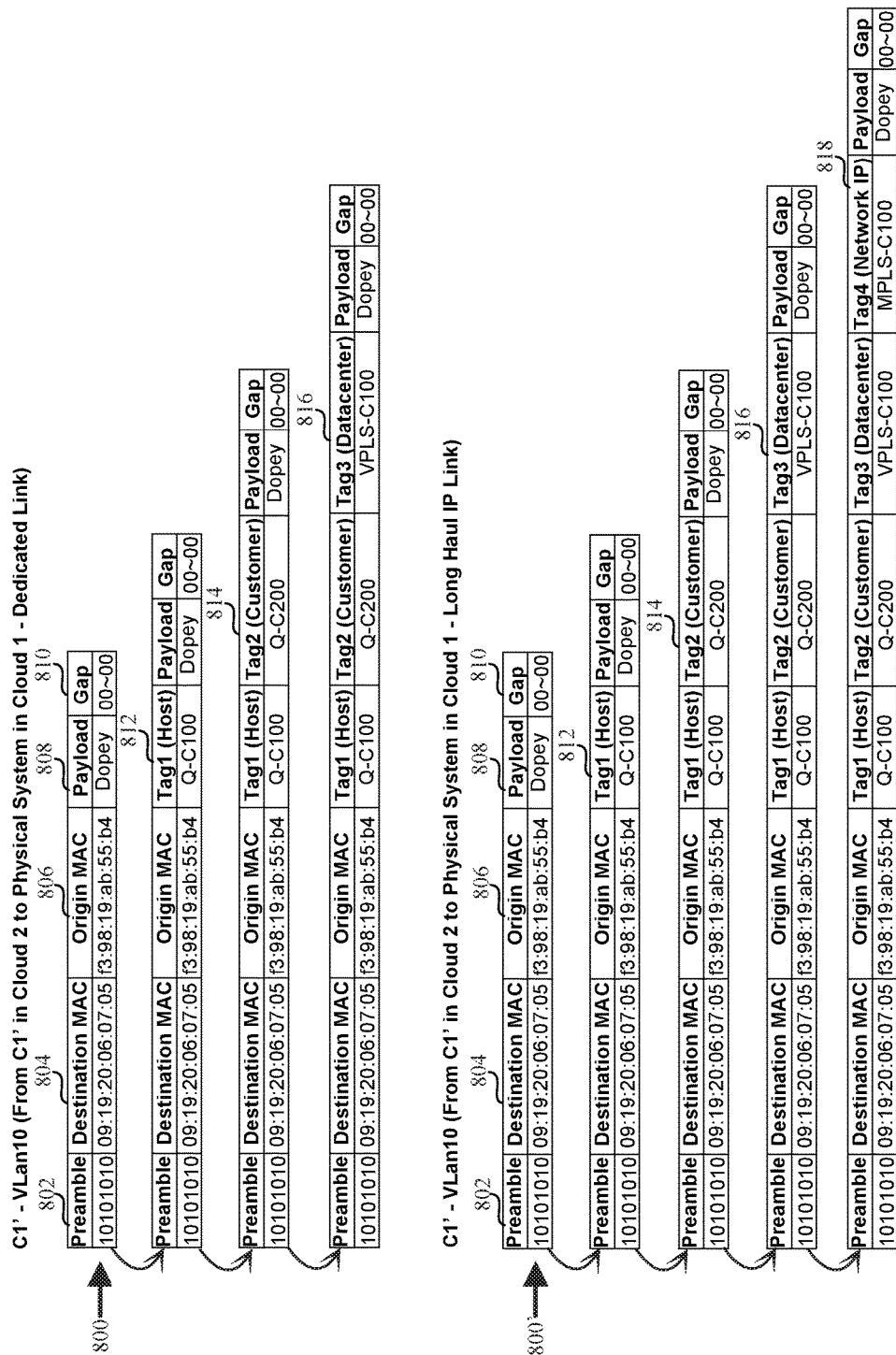
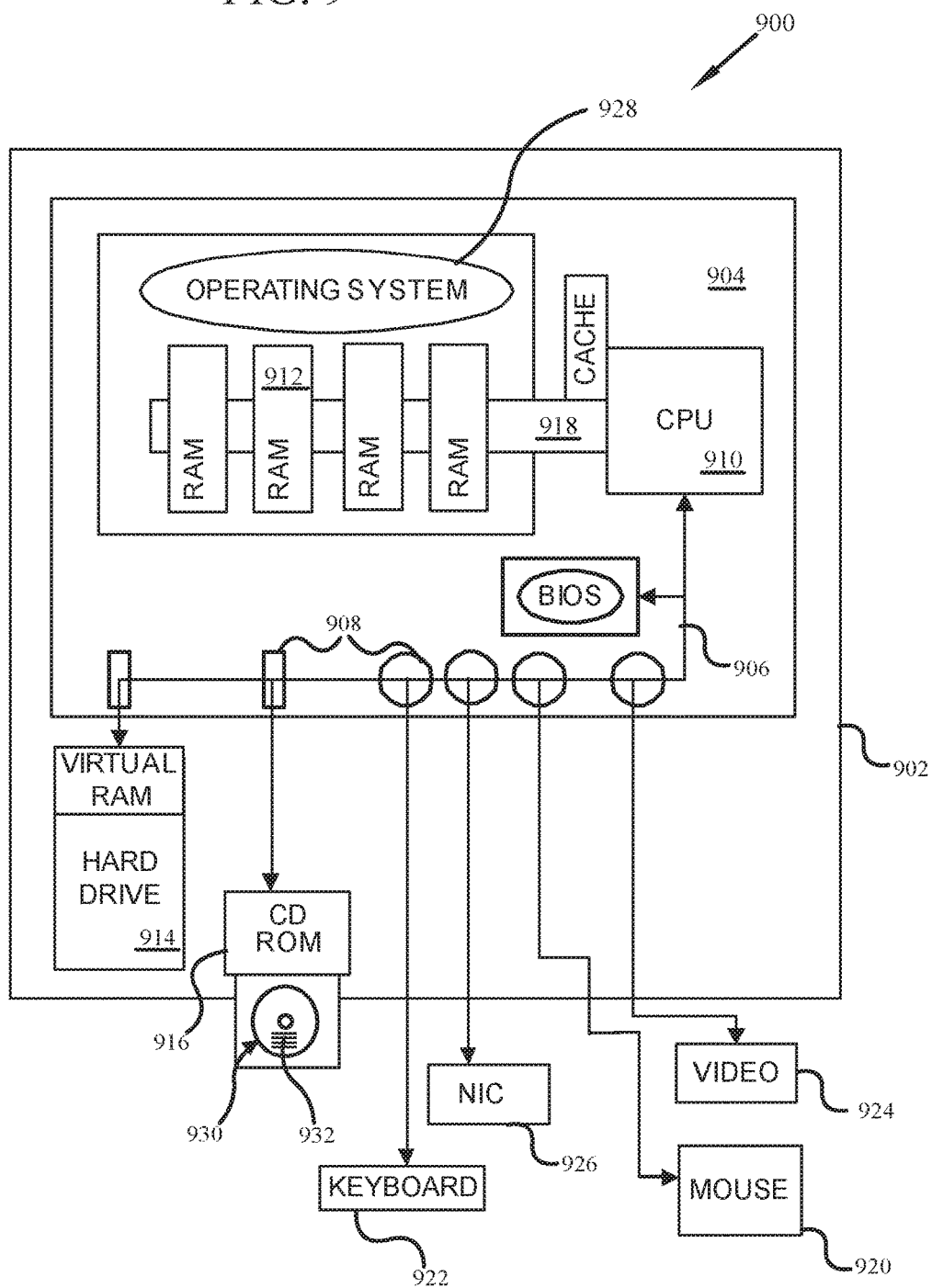


FIG. 9



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

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is a continuation of U.S. patent application Ser. No. 14/621,320 filed Feb. 12, 2015, published as US2016/0241419, now U.S. Pat. No. 9,621,374, the disclosure of which is incorporated herein by reference, which in turn is a continuation of U.S. patent application Ser. No. 13/356,555 filed Jan. 23, 2012, published as US2013/0188512, now U.S. Pat. No. 9,571,301, the disclosure of which is incorporated herein by reference. This continuing application claims the benefit of the filing date of U.S. patent application Ser. No. 13/356,555, filed Jan. 23, 2012.

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, 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/de segmentation 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

5

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. . . . It is also understood and appreciated that each client system **102** has an initial client defined network configuration.

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, each client system **102** advantageously maintains the ability to define and control their own network configuration, such as by software defined networking.

It is to be understood and appreciated that the coupling by Layer 2 is truly by Layer 2 and not as a component of a Layer 3 interaction. As noted above and as will be appreciated by those skilled in the art, OSI Layer 2 is the data link layer. At Layer 2, the exchange of data occurs through the transmission of Frames. Although Frames can and are components of Packets which are utilized at OSI Layer 3, the transfer of Frames at Layer 2 occurs without reliance on Packets at Layer 3. Moreover, although Packets and Frames are both packages of data moving through a network, Packets are specifically and fundamentally at OSI Layer

6

3—the network layer—and by its very nature is dependent on IP Protocol. The transfer of Frames at Layer 2 can and often is distinct from the transfer of Packets at Layer 3. With respect to the present invention, the coupling at Layer 2 as between the first cloud **108** and the client system **102** is an event prior to an OSI Layer 3 connection. As is further set forth below, as the present invention couples at Layer 2, the present invention permits overlapping VLANs and IP address ranges which is problematic at Layer 3. More simply stated, as the present invention couples at Layer 2 for the transfer of data frames at Layer 2, the present invention advantageously maintains each client system's **102** original network configuration and permits each client system **102** to further define and control their own network configuration.

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 MTED **100**. Moreover, at OSI Layer 3 the transfer of data elements is by Packets, and is dependent upon the IP Protocol. As such the IP address cannot overlap—if they do, then the packet routing system will have a problem in attempting to properly route packets to the correct system and the use of tags at Layer 3 will not resolve the problem. Even if Frames within the Packets are tagged, the fundamental reliance upon IP Protocol at Layer 3 dictates that overlapping IP ranges are still problematic regardless of whether or not some element of frame tagging is attempted. On the other hand, because the present invention utilized Layer 2, and the coupling is prior to an OSI Layer 3 connection, the problematic issues of IP range overlap at Layer 3 are simply not an issue.

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. Again, the use of OSI Layer 2 tags and the transfer of Frames at OSI Layer 2 as distinct from OSI Layer 3 Packets is a distinct and advantageous component of MTDC 100.

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, Tag 1—the host tag 612—is shown as Q-A100 and Tag2—the customer tag 614—is shown as Q-A200.

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, MPLS tags, Segment ID Layer 2 tags and or Global VLAN Layer 2 tags. Moreover, in varying embodiments, the OSI Layer 2 tags employed are selected from the group consisting of QinQ tags, MPLS tags, VPLS tags, Segment ID tags, Global VLAN 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.

In addition, 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 as the physical connection of a data channel for the transfer of data frames distinct from OSI Layer 3 communications, the first cloud 108 thereby virtually extending the physical infrastructure resources 106 of each physical client system 102.

Further, 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, prior to an OSI Layer 3 connection, as the physical connection of a data channel for the transfer of data frames, each frame having a plurality of OSI Layer 2 tags permitting at least two client systems to have overlapping VLANs and or overlapping IP address ranges, 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 installations 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 it's 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 changing 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.

11

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, Segment ID tags, Global VLAN tags and combinations thereof are exemplary of Layer 2 tags permitting Layer 2 extension, and are not exclusive limitations.

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, Segment ID tags, Global VLAN 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. Again, it is the coupling at OSI Layer 2 as opposed to the more common OSI Layer 3 and the distinct use of Layer 2 frames apart packets at OSI Layer 3 which advantageously permit the present invention to achieve this dynamic extension of at least one physical client system's physical infrastructure resources, including the potential overlap of IP address ranges and or overlapping VLANs. Network interconnection performed at OSI Layer 3 and reliant upon OSI Layer 3 can not achieve these advantages.

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

12

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:al: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:al: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 C1', 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 Tag 1 **812**, Tag2 **814** and Tag3 **816**. Tag3 **816** is identifying the datacenter having the resource, specifically 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, 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, Segment ID tags, Global VLAN 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.

15

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 infrastructure 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 microprocessor (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

16

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 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 datacenter, utilizing Open System Interconnection (OSI) Layer 2 tags to distinguish transmission data in Layer 2 Frames, comprising:

a plurality of client systems coupled to a first datacenter each client system having a set of infrastructure resources and a client defined networking configuration; and

a first cloud computing environment established in the first datacenter, and coupled to the client systems by OSI Layer 2 as the physical connection of a data channel for the transfer of data frames at OSI Layer 2, each frame having a plurality of OSI Layer 2 tags, the plurality of OSI Layer 2 tags permitting the distinguished transmission of data to permit at least two client systems to have overlapping network configurations.

2. The datacenter of claim 1, wherein the plurality of OSI Layer 2 tags permits at least two client systems to have overlapping Virtual Local Area Networks (VLANs) and or overlapping Internet Protocol (IP) address ranges.

3. The datacenter of claim 1, wherein overlapping network configurations permits at least two client systems to have overlapping VLANs and or overlapping IP address ranges.

4. The datacenter of claim 1, wherein the first cloud computing environment virtually extends the infrastructure resources of at least one client system.

5. The datacenter of claim 1, wherein the OSI Layer 2 tags are selected from a group consisting of: Q tags, QinQ tags, VXLAN, NVGRE, Segment ID tags and VLAN tags.

17

6. The datacenter of claim 1, wherein at least one client system is a virtual client system.

7. The datacenter of claim 1, wherein at least one client system is a physical client system.

8. The 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 at OSI Layer 2.

9. The datacenter of claim 1, wherein the transfer of frames at OSI Layer 2 occurs without reliance on Packets at OSI Layer 3 and above.

10. The datacenter of claim 1, wherein each client may direct software defined networking.

11. The datacenter of claim 1, wherein the plurality of OSI Layer 2 tags permitting distinguished data transmission are applied to a Frame that encapsulates the client defined network configuration.

12. A method for providing a datacenter, utilizing Open System Interconnection (OSI) Layer 2 tags to distinguish transmission data in Layer 2 Frames, comprising:

establishing within a first datacenter a first cloud computing environment;

locating at least one client system in the first datacenter, each client system having a set of infrastructure resources and a client defined networking configuration; and

coupling the at least one physical client system to the first cloud computing environment by OSI Layer 2 as the physical connection of a data channel for the transfer of data frames at OSI Layer 2, each frame having a plurality of OSI Layer 2 tags, the plurality of OSI Layer 2 tags permitting the distinguished transmission of data to permit at least two client systems to have overlapping network configurations.

13. The method of claim 12, wherein the plurality of OSI Layer 2 tags permits at least two client systems to have overlapping Virtual Local Area Networks (VLANs) and or overlapping Internet Protocol (IP) address ranges.

14. The method of claim 12, wherein overlapping network configurations permits at least two client systems to have overlapping VLANs and or overlapping IP address ranges.

15. The method of claim 12, wherein the first cloud computing environment virtually extends the infrastructure resources of at least one client system.

16. The method of claim 12, wherein the OSI Layer 2 tags are selected from a group consisting of: Q tags, QinQ tags, VXLAN, NVGRE, Segment ID tags and VLAN tags.

17. The method of claim 12, wherein at least one client system is a virtual client system.

18. The method of claim 12, wherein at least one client system is a physical client system.

19. The method of claim 12, 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.

20. The method of claim 12, wherein the transfer of frames at OSI Layer 2 occurs without reliance on Packets at OSI Layer 3 and above.

21. The method of claim 12, wherein each client may direct software defined networking.

22. The method of claim 12, wherein the plurality of OSI Layer 2 tags permitting distinguished data transmission are applied to a Frame that encapsulates the client defined network configuration.

23. A datacenter, utilizing Open System Interconnection (OSI) Layer 2 tags to distinguish transmission data in Layer 2 Frames, comprising:

18

a first datacenter providing 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;

a second datacenter providing 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 coupled to the first datacenter by OSI Layer 2 as the physical connection of a data channel for the transfer of data frames at OSI Layer 2, each frame having a plurality of OSI Layer 2 tags, the plurality of OSI Layer 2 tags permitting at least two systems utilizing the coupled first datacenter and second data center to have overlapping network configurations.

24. The datacenter of claim 23, further comprising:

a plurality of client systems coupled to one or both of the first datacenter and the second datacenter, each client system having a set of infrastructure resources and a client defined networking configuration, each client system coupled to the 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 permitting the distinguished transmission of data to permit at least two client systems to have overlapping network configurations.

25. The datacenter of claim 24, wherein at least one client system is a virtual client system.

26. The datacenter of claim 24, wherein at least one client system is a physical client system.

27. The datacenter of claim 24, wherein each client may direct software defined networking.

28. The datacenter of claim 24, wherein the first cloud computing environment virtually extends the infrastructure resources of at least one client system.

29. The datacenter of claim 24, wherein the plurality of OSI Layer 2 tags permits at least two client systems to have overlapping Virtual Local Area Networks (VLANs) and or overlapping Internet Protocol (IP) address ranges.

30. The datacenter of claim 24, wherein overlapping network configurations permits at two client systems to have overlapping VLANs and or overlapping IP address ranges.

31. The datacenter of claim 24, wherein the OSI Layer 2 tags are selected from a group consisting of: Q tags, QinQ tags, VXLAN, NVGRE, Segment ID tags and VLAN tags.

32. The datacenter of claim 24, wherein the transfer of frames at OSI Layer 2 occurs without reliance on Packets at OSI Layer 3 and above.

33. The datacenter of claim 24, wherein the plurality of OSI Layer 2 tags permitting distinguished data transmission are applied to a Frame that encapsulates the client defined network configuration.

34. A method for providing a datacenter having Open System Interconnection (OSI) Layer 2 architecture to maintain original client Layer 2 configurations 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;

19

rations, 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 as the physical connection of a data channel for the transfer of data frames at OSI Layer 2, each frame having a plurality of OSI Layer 2 tags, the plurality of OSI Layer 2 tags permitting at least two systems utilizing the coupled first datacenter and second data center to have overlapping network configurations.

35. The method of claim 34, further comprising: disposing a plurality of client systems in one or both of the first datacenter and the second datacenter, each client system having a set of infrastructure resources and a client defined networking configuration, each client system coupled to the 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 client system; and

coupling each 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 permitting the distinguished transmission of data permitting at least two client systems to have overlapping network configurations.

20

36. The method of claim 35, wherein at least one client system is a virtual client system.

37. The method of claim 35, wherein at least one client system is a physical client system.

38. The method of claim 35, wherein each client may direct software defined networking.

39. The method of claim 35, wherein the first cloud computing environment virtually extends the infrastructure resources of at least one client system.

40. The method of claim 35, wherein the plurality of OSI Layer 2 tags permits at least two client systems to have overlapping Virtual Local Area Networks (VLANs) and or overlapping Internet Protocol (IP) address ranges.

41. The method of claim 35, wherein overlapping network configurations permits at two client systems to have overlapping VLANs and or overlapping IP address ranges.

42. The method of claim 35, wherein the OSI Layer 2 tags are selected from a group consisting of: Q tags, QinQ tags, VXLAN, NVGRE, Segment ID tags and VLAN tags.

43. The method of claim 35, wherein the transfer of frames at OSI Layer 2 occurs without reliance on Packets at OSI Layer 3 and above.

44. The method of claim 35, wherein the plurality of OSI Layer 2 tags permitting distinguished data transmission are applied to a Frame that encapsulates the client defined network configuration.

* * * * *