Intel Cloud Orchestration Networking Design Document

Abstract

This document outlines the design considerations for the implementation of Open vSwitch and other networking technologies in the Cloud Integrated Advanced Orchestrator (Ciao), Intel Corporation's advanced cloud orchestration software. It describes the various techniques, structure, and technology choices that will be used in the execution of our project.

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Authorship: Matthew Johnson, Cody Malick, and Garrett Smith

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CONTENTS

I. Introduction

Our project is to first switch the Linux-created GRE tunnel implementation in Ciao to use GRE tunnels created by Open vSwitch. From that point we will switch the actual tunneling implementation from GRE to VxLAN/nvGRE based on performance measurements of each on data center networking cards. After this is completed, a stretch goal is to replace Linux bridges with Open vSwitch switch instances. This document outlines the steps, techniques, and methodology we will utilize to achieve each goal.

A. Purpose

The current implementation of Ciao tightly integrates software defined networking principles to leverage a limited local awareness of just enough of the global cloud's state. Tenant overlay networks are used to overcome traditional hardware networking challenges by using a distributed, stateless, self-configuring network topology running over dedicated network software appliances. This design is achieved using Linux-native Global Routing Encapsulation (GRE) tunnels and Linux bridges, and scales well in an environment of a few hundred nodes.

While this initial network implementation in Ciao satisfies current simple networking needs in Ciao, all innovation around software defined networks has shifted to the Open vSwtich (OVS) framework. Moving Ciao to OVS will allow leverage of packet acceleration frameworks like the Data Plane Development Kit (DPDK) as well as provide support for multiple tunneling protocols such as VxLAN and nvGRE. VxLAN and nvGRE are equal cost multipath routing (ECMP) friendly, which could increase network performance overall.

B. Scope

Ciao exists as a cloud orchestrator for cloud clusters. It is inherently necessary for the separate nodes in the cloud cluster to be able to talk to each other. Without a reliable and secure software defined network, Ciao would have little purpose. Utilization of Open vSwitch GRE tunnels allows Ciao to become more scalable and enables the inclusion of packet-acceleration technology such as the Data Plane Development Kit (DPDK).

C. Context

Our networking mode will exist within Ciao, a cloud orchestrator designed to be fast and easy to deploy. Ciao is sectioned into three parts, each with distinctive purposes [1].

Controller Responsible for policy choices around tenant workloads [1].

Scheduler The Scheduler implements a "push/pull" scheduling algorithm. In response to a controller approved workload instance arriving at the scheduler, it finds a first fit among cluster compute nodes currently requesting work [1].

Launcher The Launcher abstracts the specific launching details for the different workload types (eg: virtual machine, container, bare metal). Launcher reports compute node statistics to the scheduler and controller. It also reports per-instance statistics to the controller [1].

Our networking mode must facilitate the communication of packets between all three levels of Ciao, as well as individual compute and network nodes and the Compute Node Concentrator (CNCI) [2].

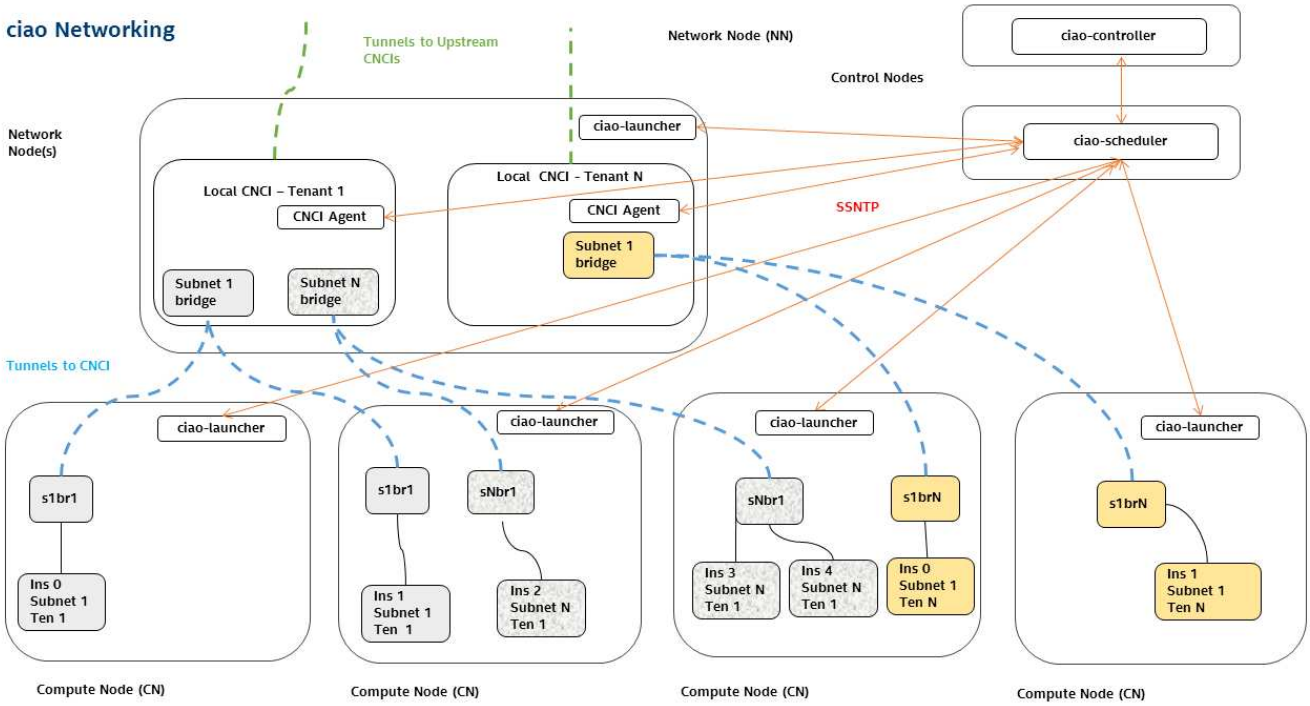
Compute Node A compute node typically runs VM and Container workloads for multiple tenants [2].

Network Node A Network Node is used to aggregate network traffic for all tenants while still keeping individual tenant traffic isolated from all other the tenants using special virtual machines called Compute Node Concentrators (CNCIs) [2].

Compute Node Concentrator (CNCI)
CNCIs are Virtual Machines automatically configured by the ciao-controller, scheduled by the ciao-scheduler on a need basis, when tenant workloads are created [2].

Specifically, the Ciao network components must communicate securely using the Simple and Secure Node Transfer Protocol (SSNTP). The network node aggregates traffic between compute nodes while keeping the tenant traffic isolated from other tenants in the cluster. Network nodes achieve this with CNCIs. A graphic of the lowest-level of this network configuration shows their relation to each other.

Fig. 1. Ciao Network Topology [3]



D. Summary

We will implement an Open vSwitch Generic Routing Encapsulation (OVS-GRE) mode in Ciao in order to leverage DPDK and other software defined networking technology innovations which are dependent on OVS. This document will outline our design strategy, design views, and design viewpoints for each component of our solution.

II. References

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III. Glossary

Bridge Software or hardware that connects two or more network segments.

Ciao Ciao is a cloud orchestrator that provides an easy to deploy, secure, scalable cloud orchestration system which handles virtual machines, containers, and bare metal apps agnostically as generic workloads. Implemented in the Go language, it separates logic into ”controller”, ”scheduler” and ”launcher” components which communicate over the ”Simple and Secure Node Transfer Protocol (SSNTP)” [1].

Cloud A huge, amorphous network of servers somewhere [4].

Cloud Orchestration A networking tool designed to aid in the deployment of multiple virtual machines, containers, or bare-metal applications [1].

Compute Node Concentrator (CNCI)
Virtual Machines automatically configured by the ciao-controller, scheduled by the ciao-scheduler on a need basis, when tenant workloads are created [2].

Data Plane Developement Kit (DPDK)
DPDK is a set of libraries and drivers for fast packet processing. It was designed to run on any processors. The first supported CPU was Intel x86 and it is now extended to IBM Power 8, EZchip TILE-Gx and ARM. It runs mostly in Linux userland [5].

Equal Cost Multipath Routing (ECMP)
Equal cost multipath routing is a routing strategy in which next path routing for a packet can occur along one of several equal-cost paths to the destination [6].

Generic Routing Encapsulation (GRE)
Encapsulation of an arbitrary network layer protocol so it can be sent over another arbitrary network layer protocol [7].

Linux Bridge Configurable software bridge built into the Linux kernel [8].

Network Node (NN) A Network Node is used to aggregate network traffic for all tenants while still keeping individual tenant traffic isolated from all other the tenants using special virtual machines called Compute Node Concentrators (CNCIs) [2].

nvGRE	Network Virtualization using Generic Routing Encapsulation [9].
Open vSwitch	Open source multilayer software switch with support for distribution across multiple physical devices [10].
OVS	Open vSwitch [10].
Packet Acceleration	Increasing the speed of the processing and transfer of network packets.
Packet Encapsulation	Attaching the headers for a network protocol to a packet so it can be transmitted using that protocol [11].
SSNTP	The Simple and Secure Node Transfer Protocol (SSNTP) is a custom, fully asynchronous and TLS based application layer protocol. All Ciao components communicate with each others over SSNTP [12].
Tunnel	Point to point network connection that encapsulates traffic between points [11].
VxLAN	Virtual Extensible Local Area Network [13].

IV. Body

A. Design Stakeholders

The stakeholders are Intel, and the members of the Oregon State University capstone group working on the project, Matthew Johnson, Cody Malick and Garrett Smith. Additional stakeholders are the existing and future users of Ciao.

B. Design Concerns

The design concerns are the platforms that need to be supported, the implementation of Open vSwitch created GRE tunnels, the implementation of VxLAN tunnels, the implementation of nvGRE tunnels, gathering performance metrics for the tunneling implementations, replacing the Linux bridges used by Ciao with Open vSwitch switch instances, logging, and testing. The capstone group members are stakeholders interested in all of the design concerns because they will be implementing all of the concerns. Intel is interested in all of the design concerns because they are the clients and they will be using Ciao.

C. Context Design Viewpoint

The context design viewpoint used here is from the IEEE 1016-2009 standard [14].

1) Context Design Concerns: The design concerns for the context viewpoint are related to overall compatibility both with the platform the software is running on as well as the software the networking mode is running in. It must also be compatible with existing networking protocols as used within Ciao already. Other major concerns include security and performance of the software defined network.

There is one primary use case initiated by a compute node sending a data packet to another compute node within the SDN.

Actor	Compute Node 1
Precondition	Compute Node 1 attempts to send data over network to Compute Node 2.
Postcondition	Compute Node 2 receives data sent by Compute Node 1
Main Path	1) Compute Node 1 encapsulates packet. 2) Compute Node 1 sends packet to Network Node. 3) Network Node routes packet via relevant CNCI to Compute Node 2. 4) Compute Node 2 receives packet and de-encapsulates.

2) Design Entities: The users of the networking mode we are implementing are the current and future users of Ciao, system administrators of small to medium enterprises running private clouds.

The actors of the networking mode are the components of Ciao networking, the compute nodes, network nodes, and CNCIs. These nodes handle the encapsulation, routing, and de-encapsulation of packets.

3) Design Relationships: Compute nodes both send and receive packets to other compute nodes. Network nodes aggregate this tenant network traffic while CNCIs within the network nodes keep tenant traffic isolated from each other.

4) Design Constraints: Design of the solution must integrate fully with Ciao as well as the Linux family of operating systems it runs on. This constraint demands specific technology choices as described below in the Context Design View section.

D. Context Design View

Compatibility with the rest of the Ciao system is paramount and drives many design decisions. The network implementation will be done in the Go programming language.

Because compatibility with the reset of the Ciao system is paramount, our software defined network will be written in the Go programming language and fully integrated in to Ciao. The Go programming language was selected for several reasons, including the efficiency of the language regarding both speed and memory, the concurrency capabilities, and the ease of implementation. Go was compared against C and Python as alternatives, and prevailed in every criteria except for availability of the language.

This network mode will be written as a standalone networking mode for Ciao as an additional option to the standard Linux bridges available now. For this reason, it must be fully integrated with the Ciao networking framework as it currently exists [2].

Since Ciao targets the Linux family of operating systems, our networking solution must also support Linux operating systems.

E. Interface Design Viewpoint

One of the main project goals is switching the GRE tunneling implementation from standard GRE tunnels to Open vSwitch generated GRE tunnels. The implementation of this object will be through designing and building an interface for Open vSwitch to hook into Ciao.

1) Design Concerns: Ciao will need to implement an interface for Open vSwitch in order to utilize the new feature set that OVS supplies. In order to access the OVS Management Database, we will need to interface with the Open vSwitch Database Management Protocol[15]. The following functions of the protocol will need to be created:[15]

Function Name	Parameters	Description
Insert	*table* : required *row* : required *id* : optional	The operation inserts specified value into table at row. If no id is specified, then a new unique id is generated.
Select	*table* : required *where* : required *columns* : optional	Searches *table* for rows that match all the conditions specified in *where*. If *columns* is not specified, all columns from the table are returned.
Update	*table* : required *where* : required *row* : required	Updates specified rows in a table. It searches *table* for rows that match all conditions specified in *where*.
Delete	*table* : required *where* : required	Operation deletes all the rows from *table* that match all the conditions specified in *where*

2) Design Elements: The primary method of interaction with Open vSwitch is through the Configuration Management Database, which provides a programmatic interface for updating and changing OVS on the fly. This will be the primary interface for our implementation.

F. Interface Design View

In order to interact with the interface using the Go programming language, the implementation will use the libovsdb library[16]. Libovsdb provides a direct interface for Go to access and modify the OVS Database configurations. The following is an example function call to call the above functions:[17]

Listing 1. Example insert operation in the OVS Database

```
// simple insert operation
```

```
insertOp := libovsdb.Operation{
    Op:     "insert",
    Table:  "Bridge",
    Row:    bridge,
    UUIDName: namedUUID,
}
```

Using the above code, slightly altered for each required operation, Go can be used to insert, select, update, and delete using a standard format.

G. Interaction Design Viewpoint

An important part of implementation is choosing a tunneling protocol to communicate between compute nodes. Currently, standard Generic Routing Encapsulation is used to create a virtual network. These tunnels are created at the Ethernet layer, and allow distributed systems to believe they are on the same physical network as another computer in a different location.

1) Design Concerns: While GRE tunnels get the job done, a new and more modern protocol is needed to support advanced virtualization features and scaling to large address spaces.

H. Interaction Design View

VxLAN is a relatively new virtualization standard developed by a few major players in the network industry. Cisco, VMware, Citrix, and Redhat all worked together to create this standard to resolve the major problem of massive virtual networks. VxLAN's primary advantage is that it has a massive address space, about sixteen million, and that its overall overhead increase is only fifty bytes [18]. Speed will be a deciding factor in which interface is chosen, so a smaller overhead is good.

NvGRE is another relatively new virtualization standard developed in tandem by Microsoft, HP, Intel, and Dell [19]. NvGRE sports a few of the same features as VxLAN, the primary difference between the two being the header field. They use different UDP port numbers and use a different bit to indicate that encapsulation has occurred [20]. The primary difference between the two is going to be overall performance in our testing environment, and in production.

Part of the implementation is selecting a more advanced tunneling protocol than standard GRE tunnels. The project will be implementing both nvGRE, and VxLAN, and testing the performance of both protocols in order to determine the best fit. Both protocols implement improved and more modern versions of tunneling software.

I. Resource Design Viewpoint

The resource design viewpoint used here is from the IEEE 1016-2009 standard [14]. We must provide explicit performance metrics for our SDN implementation. These metrics will be what we use to determine how our SDN implementation compares against the preexisting Ciao SDN implementation. The performance metrics must have numbers we can use to calculate actual and percentage differences in bandwidth and latency.

1) Design Concerns: The resource viewpoint was chosen because it covers the concerns of resource utilization and performance for the network and servers Ciao is running on. The specific resources we are interested in when gathering performance metrics for are network bandwidth and latency, and server CPU usage.

2) Design Elements: To compare our changes to Ciao with the current implementation, and decide which tunneling protocols to use in our final implementation we need to gather performance metrics. We will measure network bandwidth, latency, and CPU the usage of the hardware the SDN is running on before we make any changes, and using different tunneling protocols.

J. Resource Design View

To improve network performance we will use either the VxLAN or nvGRE tunneling protocol. We will gather performance metrics for the Ciao SDN when it is using the VxLAN and nvGRE tunneling protocols, and decide which protocol to use depending on which protocol performs better. Bandwidth and throughput are the most important performance metrics. To measure the performance metrics for the tunneling protocols we will use the iperf3 [21] and qperf [22] network tools. We will use iperf3 to measure network bandwidth and CPU usage. We will use qperf to measure network latency.

1) Design Elements:

a) iperf3: The iperf3 tool will be used to gather network bandwidth measurements, and the CPU usage of machines sending and receiving network traffic. We can run iperf3 in a Docker container. There is a public Docker image we can use so we will not need to build a Docker image for it [23]. The iperf3 tool must be run in a client server configuration. The docker image supports running iperf3 in either client or server mode. We will measure network bandwidth between different tenants on the network by running the iperf3 docker container in server mode on one tenant, and in client mode on other tenants. We can measure the CPU usage at the same time as the bandwidth because iperf3 will output both at the same time.

Listing 2. Running an iperf3 docker container in server mode

```
docker run -it --rm --name=iperf3-server -p 5201:5201 networkstatic/iperf3 -s
```

Listing 3. Running an iperf3 docker container in client mode

```
docker run -it --rm networkstatic/iperf3 -c 172.17.0.2
```

b) qperf: The qperf tool will be used to gather network latency measurements. We can run qperf in a Docker container. There is a public docker image we can use so we will not need to build our own qperf docker image qperf must be run in a client server configuration. The docker image supports running in either client or server mode. To measure TCP latency the `tcp_lat` flag must be passed to the qperf client. To measure UDP latency the `udp_lat` flag must be passed to the qperf client.

Listing 4. Running a qperf docker container in server mode

```
docker run -dti -p 4000:4000 -p 4001:4001 arjanschaaf/centos-qperf -lp 4000
```

Listing 5. Running a qperf docker container in client mode to measure TCP and UDP latency

```
docker run -ti --rm arjanschaaf/centos-qperf 172.17.0.2 -lp 4000 -ip 4001 tcp_lat
    udp_lat
```

K. Design Rationale

Our design decisions were based largely around the goal of maintaining compatibility with Ciao and the platforms that Ciao runs on, as well as improving the capabilities and performance of Ciao's SDN. Implementation will be done in Go in order to integrate with the larger system and because the Go programming language is platform independent [24].

Open vSwitch was chosen because of the various features offered. OVS has support for packet acceleration frameworks such as DPDK and advanced SDN tunneling protocols such as nvGRE and VxLAN which would allow leverage of ECMP routing and potentially increase network performance.

V. SIGNATURES

_____ Robert Nesius, Engineering Manager

_____ Matthew Johnson

_____ Garrett Smith

_____ Cody Malick