Cross-Layer Fault Management in Network Function Virtualization

Feng Liu
Huawei European Research Center
Riesstr.25, München, Germany

***Abstract*—Fault management (FM) play a vital role in the daily operation of teleco providers, however, Network Function Virtalization (NFV), despite its glorious technical advantages, aggravates FM in multiple ways: *first*, each abstraction layer has its own approaches to treat faults, coordination between them is still a missing piece; *secondly*, an effective FM system at each single layer does not necessarily lead to an overall efficient FM system. A cross-layer FM system is therefore needed. In this paper, we analyze in details the scenario, problems and challenges faced by constructing such a system.**

I. Introduction

Thank its flexibility which directly leads to significant savings on OPEX & CAPEX as well as its increased agility on service innovations, the concept of NFV [1] has been prevailing recently among teleco service operators. The fundamental idea behinds NFV is to build virtualized software network devices based on the hypervisor and Commercial-Off-The-Shelf (COTS) hardware. The infrastructure on which NFV is based is thus not built specifically for high reliability and availability purposes; on the other hand, teleco services normally requires five nines of availability which is about an annual outage time of 5 minutes. Providers are now facing with the dilemma: while enjoying high flexibility and saving costs, they have to accept the risks of reliability. In the context of NFV, *faults have to be taken as facts rather than exceptions*. Currently, this is also one of the major reasons which hold back the teleco operators to adopt NFV system in their operational environment.

To tackle this dilemma, a highly efficient fault management system is needed to deal with and compensate the un-reliable soft- and hardware systems. As prescribed by many literature on reliability and availability [2], FM including detection of system faults and toleration as well as isolation of system anomalies. Finally impacted system should be recovered and services restored in a timely manner. One may argue however that each layer involved in the holistic NFV system already possesses its own mechanism to deal with fault, however a fundamental question in this case one should rise: is it enough to have a collection of individual FM systems to make a holistically efficient NFV FM system? If not, what can be done about it? In this paper, we elaborate to analyze and clarify the problematics. The purpose of this paper is to identify gaps and research challenges of building of highly efficient NFV FM system. This paper is organized as follows: Section II presents a typical NFV scenario, on which our further discussions are based; in Section III we make a in-depth analysis of the issues and problems involved in FM of NVF and try to crystallize research challenges; in Section IV we discuss research issues and a roadmap to solve this complex problem of cross-layer FM.

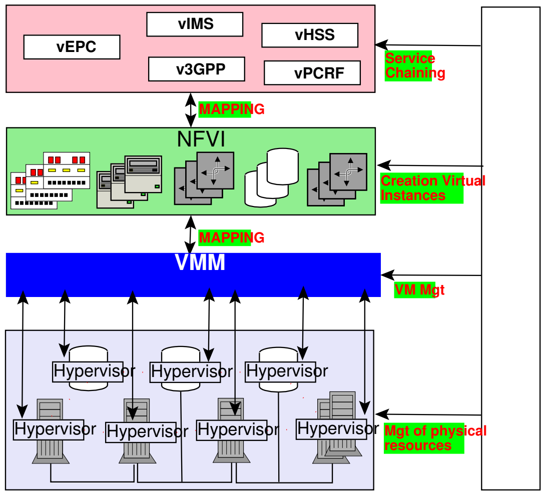

Fig. 1. NFV Reference Architecture

II. Scenario

In this discussion we use ETSI's NFV architectural model [1] as our main reference model. Accordingly, the NFV architecture can be classified into three layers: the first layer is comprised of hardware resources including computing, storage and network devices, on which physical computing and communication take place. Typically, this layer is built on computing clusters with high-performance storage and networking devices. The second layer is virtualization layer where one or more hypervisors virtualize hardware's computing, communication and storage capabilities into sharable virtual resources, some example of hypervisors suitable for such tasks are, KVM, Xen or VMware, etc. Virtualization layer manages physical resources by means of scheduling the usage of CPU cycle, network interface virtualization (vNIC) or block storage devices through a pre-defined virtual infrastructure to hardware interface (VI-Ha). Having the virtualization resources provisioned, virtual infrastructures are now managed by platform such as OpenStack [3] or CloudStack [4] for sharing among multiple tenants for service implementation. A vertial component commonly known as Management and Netowork Operation (MANO) is supposed to deal with management activities on different layers and assist users to orchestrate NFV services on the top.

TABLE I. SPECIFIC FM APPROACHES TO DIFFERENT NFV LAYERS

Layer	Typical HA Approaches	Example
Physical	Heartbeat, Fencing, Hot/Cold Standby, Reliable Messaging Bus	LinuxHA Project, Pacemaker, cman
Hypervisor	Virtual Resource Monitoring, Live Migration	VMWare HA, HA-Lizard
Virtual Network Functions	Application-specific FM methods	vendor specific application
Virtual Services	Traditional Network Service OSS/BSS	SNMP or other vendor specific methods to manage faults of virtual devices

III. PROBLEM STATEMENT

The central challenge in the cross-layer fault management lays in the coordination of various FM appraoches from different layers involved in the NFV architecture and, frequently, also within individual layers. We classify those problem in *vertical* and *horizontal* dimensions. In this section, we analyze research problems in details accrodingly to the above mentioned dimensions, then we provide a scenario that clarify an uncoordinated FM will aggreviate the holistic system when failures impact.

A. Problems of Vertical Integration of FM Approaches

Typically each layer of NFV architecture possesses its own specific FM approaches to ensure the services offered on this particular layer as we illustrate in the Table I. There is hardly any information exchanged between layers regarding FM and let alone the coordination of separated layers, let alone the coordinations among them. We argue that such a separate approach does not meet requirements of a high efficient overall FM system. Failing to do so will introduce various sorts of inconsistent problems in terms of false positives in failure detections, inconsistent fault recovery actions, which will only aggravate the holistic fault management process in general.

1) Virtualization and Physical Layers: Virtualization enables physical resources to be shared among multiple virtual instances in terms of computing, networking and storage. While there are different forms of resource virtualization, e.g. server, network, application etc., different approaches have been applied to manage the virtual instances which mostly concentrate on the efficient control of physical resources. Features such as tracking of dependencies between virtual resources and their physical mappings from the service point of view is still missing piece. Such kind of dependency tracking is essential for the reliability both from top-down and bottom-up perspective. When fault impacts virtualized resources, FM should tracking down the associated physical resources so that new resources could be employed to mitigate faults and vice versa. This requires precise mappings between layers since there could be one-to-many (aggregation) or many-to-one (sharing) relationships between virtualized and physical resources as shown in Fig.2.

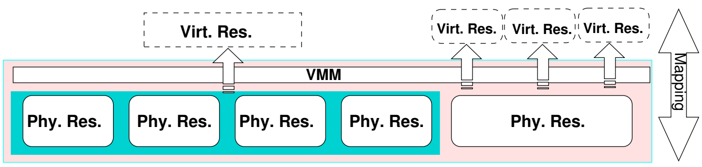

Fig. 2. Mapping of virtual and physical resources

As suggested in the Table I, on the physical layer, FM approaches such as heartbeats and fencing are usually applied to ensure the high availability of clusters. On the virtualization layer, monitoring mechanisms frequently focus on the health of virtual resources, there is hardly any communication between separate approaches. Configuration as such can introduce inconsistency not only during the FM operations, since each layer makes decisions based on its own observations of current states of its own, e.g. in a one-to-many configuration, heartbeat mechanism managing HA of physical clusters decides to apply Totem single-ring ordering and membership protocol [5] (e.g. Corosync) to shutdown and replace a node which does not respond to heartbeat, however in the same moment, management of virtual resources also detects the service degradation, but decides to migrate the complete virtual element onto other set of working nodes in their resource pool. This scenario leads to extra overhead for he unnecessary operations due to lack of communication between layers and thus inconsistency in the fault management actions derived.

2) NFVI and NFV Layers: Same mapping and consistency problems could affect NFVI and NFV layers as well, where NFVIs are virtualized teleco services elements and NFV is teleco services chained together by an orchestration function using service elements. Virtualized infrastructure is provisioned based on virtual resources prepared by hypervisors and other different means of virtualization, e.g. storage and network virtualization techniques. On NFVI layer, virtual resources are combined with specific functionalities such as vRouters, vEPC, vFirewall etc. as shown on the top layer in Fig. 1. An orchestration functions

B. Problems of Horizontal Integration of FM Approaches

1) Coordinations between Distributed Clusters:

2) Multi-Orchestrator Collaboration:

IV. RESEARCH CHALLENGES

With problems that involve in the FM of NFV clarified, in this section, we dedicate to discussion and categorization of the potential research areas and challenges need to be overcame.

V. CONCLUSION

REFERENCES

[1] "Network functions virtualisation (nfv) white paper," *European Telecommunications Standards Institute*, 2012.

[2] A. Avizienis, J.-C. Laprie, B. Randell, and C. Landwehr, "Basic concepts and taxonomy of dependable and secure computing," *Dependable and Secure Computing, IEEE Transactions on*, vol. 1, no. 1, pp. 11–33, 2004.

[3] "Openstack project," http://www.openstack.org.

[4] "Apache cloudstack project," http://cloudstack.apache.org.

[5] Y. Amir, L. E. Moser, P. M. Melliar-Smith, D. A. Agarwal, and P. Ciarfella, "The totem single-ring ordering and membership protocol," *ACM Transactions on Computer Systems (TOCS)*, vol. 13, no. 4, pp. 311–342, 1995.