《软件定义网络技术》
Software Defined Networking (SDN)

主讲人:施晓秋

SDN的起源

2005年，美国国家自然科学基金会（National Science Foundation, NSF）资助启动全球网络创新实验环境（Global Environment Networking Innovations, GENI）计划；

2006年，斯坦福大学主导，联合NSF及多个工业界厂商共同启动Clean-Slate Design for the Internet(Clean-Slate)项目。研究方向包括：网络体系结构，异构应用，异构物理层技术、安全、经济和政策。

The Mckeown Group

SDN师祖：Nick（Name）

OpenFlow: Enabling Innovation in Campus Networks

Nick McKeown
Stanford University

Tom Anderson
University of Washington

Hari Balakrishnan
MIT

Guru Parulkar
Stanford University

Larry Peterson
Princeton University

Jennifer Rexford
Princeton University

Scott Shenker
University of California, Berkeley

Jonathan Turner
Washington University in St. Louis

This article is an editorial note submitted to CCR. It has NOT been peer reviewed.
Authors take full responsibility for this article's technical content.
Comments can be posted through CCR Online.

ABSTRACT

This whitepaper proposes OpenFlow: a way for researchers to run experimental protocols in the networks they use every day. OpenFlow is based on an Ethernet switch, with an internal flow-table, and a standardized interface to add and remove flow entries. Our goal is to encourage networking vendors to add OpenFlow to their switch products for deployment in college campus backbones and wiring closets. We believe that OpenFlow is a pragmatic compromise: on one hand, it allows researchers to run experiments on heterogeneous switches in a uniform way at line-rate and with high port-density; while on the other hand, vendors do not need to expose the internal workings of their switches. In addition to allowing researchers to evaluate their ideas in real-world

to experiment with production traffic, which have created an exceedingly high barrier to entry for new ideas. Today, there is almost no practical way to experiment with new network protocols (e.g., new routing protocols, or alternatives to IP) in sufficiently realistic settings (e.g., at scale carrying real traffic) to gain the confidence needed for their widespread deployment. The result is that most new ideas from the networking research community go untried and untested; hence the commonly held belief that the network infrastructure has "ossified".

Having recognized the problem, the networking community is hard at work developing programmable networks, such as GENI [1] a proposed nationwide research facility for experimenting with new network architectures and dis-

SDN之父:Martin？（也在合影中吗？）

Ethane: Taking Control of the Enterprise

Martìn Casado, Michael J. Freedman,
Justin Pettit, Jianying Luo,
and Nick McKeown
Stanford University

Scott Shenker
U.C. Berkeley and ICSI

ABSTRACT

This paper presents Ethane, a new network architecture for the enterprise. Ethane allows managers to define a single network-wide fine-grain policy, and then enforces it directly. Ethane couples extremely simple flow-based Ethernet switches with a centralized controller that manages the admittance and routing of flows. While radical, this design is backwards-compatible with existing hosts and switches.

We have implemented Ethane in both hardware and software, supporting both wired and wireless hosts. Our operational Ethane network has supported over 300 hosts for the past four months in in Stanford University's network, and this deployment experience has significantly affected Ethane's design.

Categories and Subject Descriptors

C.2.6 [**Computer Communication Networks**]: Internetworking; C.2.1 [**Computer Communication Networks**]: Network Architecture and Design

downtime in multi-vendor networks comes from human-error and that 80% of IT budgets is spent on maintenance and operations [16].

There have been many attempts to make networks more manageable and more secure. One approach introduces proprietary middleboxes that can exert their control effectively only if placed at network choke-points. If traffic accidentally flows (or is maliciously diverted) around the middlebox, the network is no longer managed nor secure [25]. Another approach is to add functionality to existing networks—to provide tools for diagnosis, to offer controls for VLANs, access-control lists, and filters to isolate users, to instrument the routing and spanning tree algorithms to support better connectivity management, and then to collect packet traces to allow auditing. This can be done by adding a new layer of protocols, scripts, and applications [1, 10] that help automate configuration management in order to reduce the risk of errors. However, these solutions hide the complexity, not reduce it. And they have to be constantly maintained to support the rapidly changing and often proprietary management interfaces exported by the managed elements.

SDN大神-SDN的Uncle

- **Scott Shenker-加州大学伯克利分校教授，美国工程院院士**

主要贡献：

- SDN开创者之一；
- OpenFlow奠基性论文的作者之一；
- ONF的联合创始人；
- Nicira公司联合创始人；
- 计算机科学界被引用次数最多的论文作者之一

第一阶段（2006-2011）SDN的发展初期

2006

Martin领导Ethane项目，目标是提出一个新型的企业网络架构，通过集中控制简化网络模型

2007

Martin联合Nick教授、Scott教授创建网络虚拟化技术创新公司Nicira
Martin等在SIGCOMM会议上发表论文“Ethane:Taking control of the Enterprise”

2008

The McKeown Group发布了第一个开源SDN控制器NOX-Classic
Nick等在SIGCOMM会议上发表论文OpenFlow: Enabling Innovation in Campus Networks

2009

The McKeown Group发布首个基于Python语言的SDN控制器POX，同时发布了OpenFlow v1.0
SDN入选麻省理工科技评论的“未来十大突破性技术”

2010

The McKeown Group发布开源SDN网络模拟器Mininet

2011

开放网络基金会（Open Networking Foundation, ONF）成立

2012

Google发布应用SDN技术解决数据中心之间流量问题的方案B4
VMware收购Nicira，Juniper收购Contrail
思科发布SDN产品战略ONE
BigSwitch发布开源控制器Floodlight
日本NTT公司发布开源控制起Ryu

SDN的发展

- 第一阶段-SDN的发展初期（2006-2011）：提出了SDN的主要架构、设计思想和实现技术，属于学术界的研究与试验初创阶段，引起了产业界的关注；
- 第二阶段-SDN的发展中期（2012至今）：产业界开始普遍接受SDN的思想。SDN演变成以学院派、网络创新公司、传统网络巨头和运营商为代表的不同技术流派，同时，出现了更多的SDN控制器、网络操作系统、商用产品和应用案例

第二阶段（2012至今）SDN的发展中期

2018

Cisco 、Apstra等推出基于意图的网络（Intent-based Network)
VMware 推出新的NSX Cloud和NSX SD-WAN
Juniper 推出Contrail SD-WAN
HPE Aruba推出SD-Branch

2017

VMware 宣布其NSX带来10亿美元销售额。
两家重要的SD-WAN创业企业相继被收购。Cisco收购Viptela，VMware收购VeloCloud

2016

开放网络基金会(ONF)与开放网络实验室(ON.Lab)宣布进行合并。主推CORD和ONOS
思科发布了全数字化网络架构-DNA

2015

SDN在产业界加快落地，软件定义广域网(SD-WAN)商用产品的出现，使得SDN的实际应用场景不在局限于数据中心网络
中国联通发布新一代网络架构CUBE-Net2.0白皮书

2014

由斯坦福大学和加州伯克利分校SDN先驱共同成立ON.Lab，推出SDN开放网络操作系统(ONOS）
Facebook在OCP项目中开放发布自己的Wedge交换机设计细节
Juniper、戴尔、惠普等产商发布支持SDN的White Box交换机
The McKeown Group发布数据平面的高级编程语言框架(P4)
中国电信与华为联合宣布双方合作完成了全球首个运营商SDN商用部署

2013

美国AT&T、英国电信、德国电信等电信网络运营商提出了网络功能虚拟化(NFV)的概念
AT&T启动Domain2.0项目
Cisco 、 Juniper 等网络巨头发起开源项目OpenDaylight(ODL)
Cisco发布以应用为中心的基础设施 ACI

SDN发展现状与趋势

- 关注热度上升：学术界&产业界互为促进
- 应用范围扩大：SD-DC→SD-X（WAN、云&雾、Access, ）
- 市场规模增长
- 技术融合加速

学术界

国外：斯坦福大学（logo）、普林斯顿大学、康奈尔大学等；

国内：清华大学牵头，中科院计算所、北邮、东南大学、北京大学等单位参与开展了类SDN思想的”未来网络体系结构和创新环境”863项目研究。

康奈尔大学

斯坦福大学

普林斯顿大学

产业界

以Nicira 和Big Switch为代表的SDN 创业公司不断涌现；

Cisco 、Juniper、HPE、 NEC 、ARISTA、IBM 等厂商先后发布了支持OpenFlow 的SDN 交换机；自主或联合开发SDN控制器；

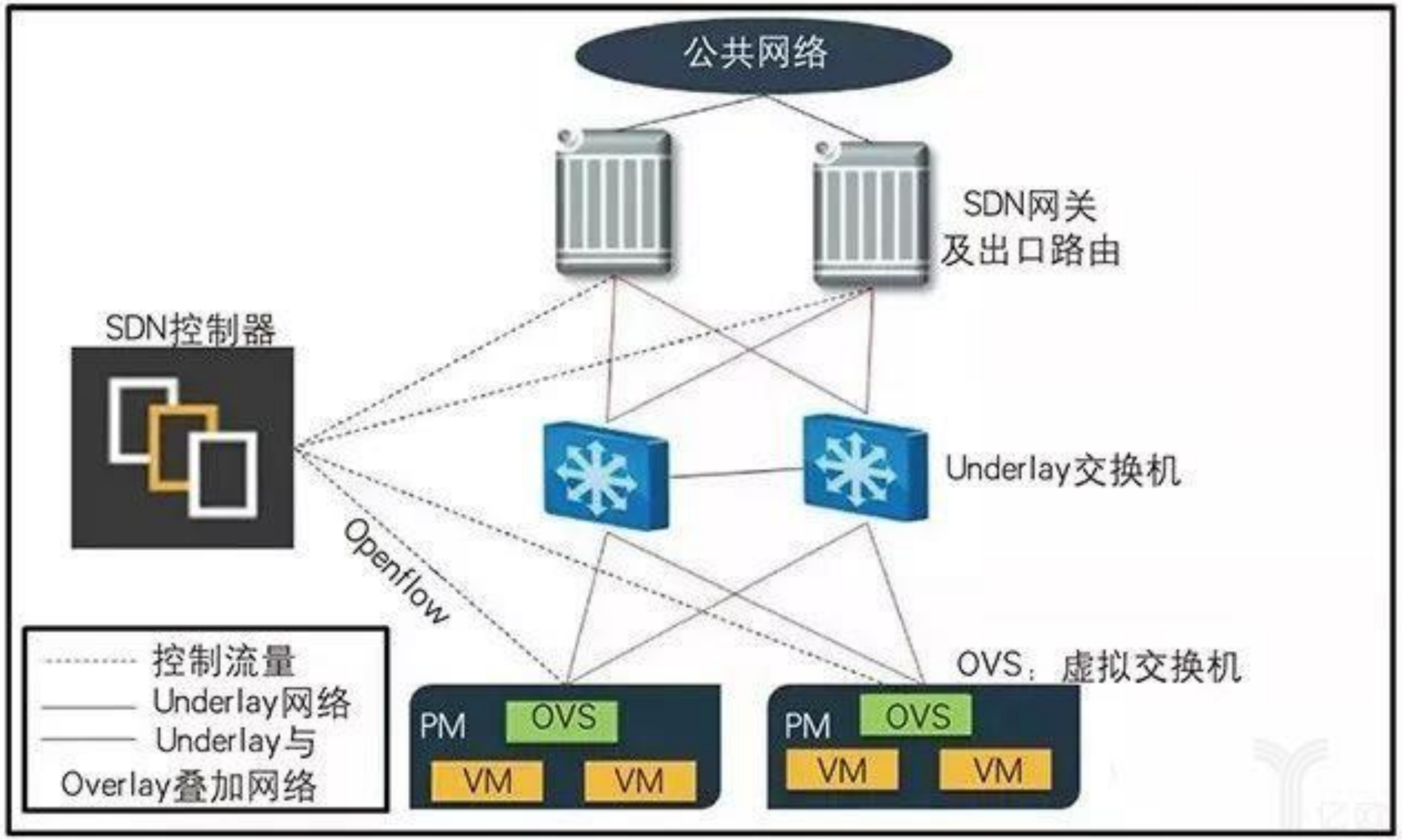
国内的华为、中兴、盛科等设备厂商，移动、联通、电信等运营商，也在SDN产品和解决方案研发上进展迅速。

SDN发展趋势

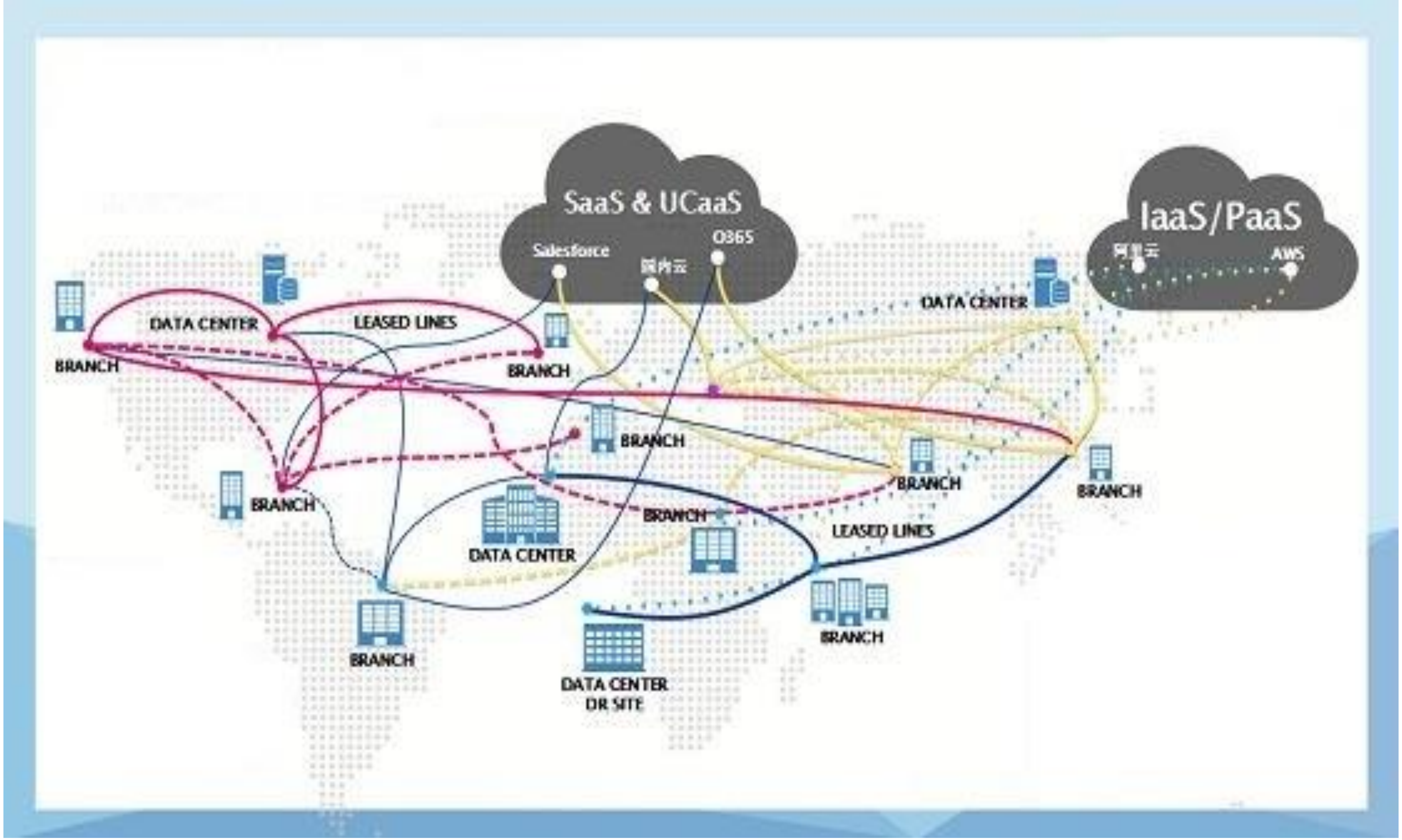
- 关注热度上升：学术界、产业界
- 应用范围扩大：SD-X（DC、WAN、云&雾、Access ）
- 市场规模增长
- 技术融合加速

应用场景-数据中心（SD-DC）

SDN云数据中心典型网络架构

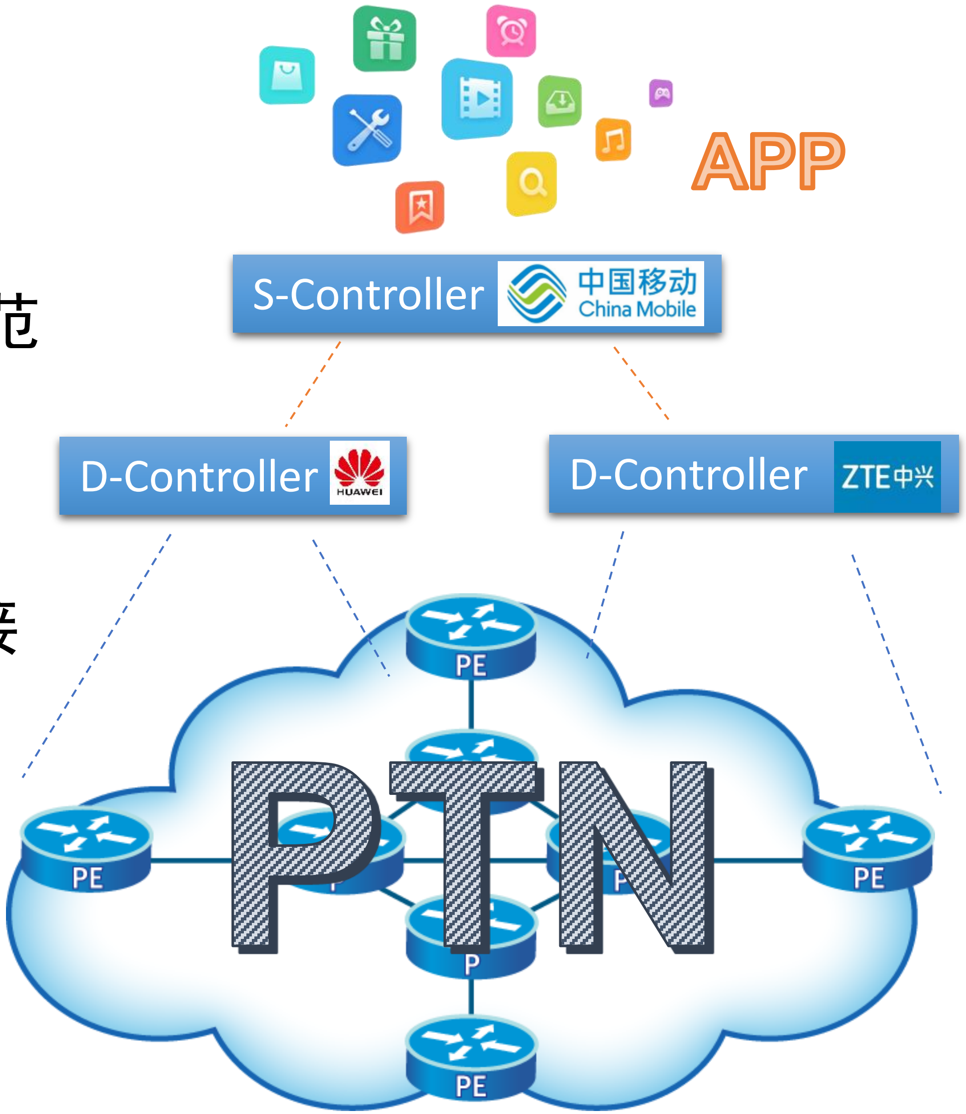


应用场景-广域网（SD-WAN）

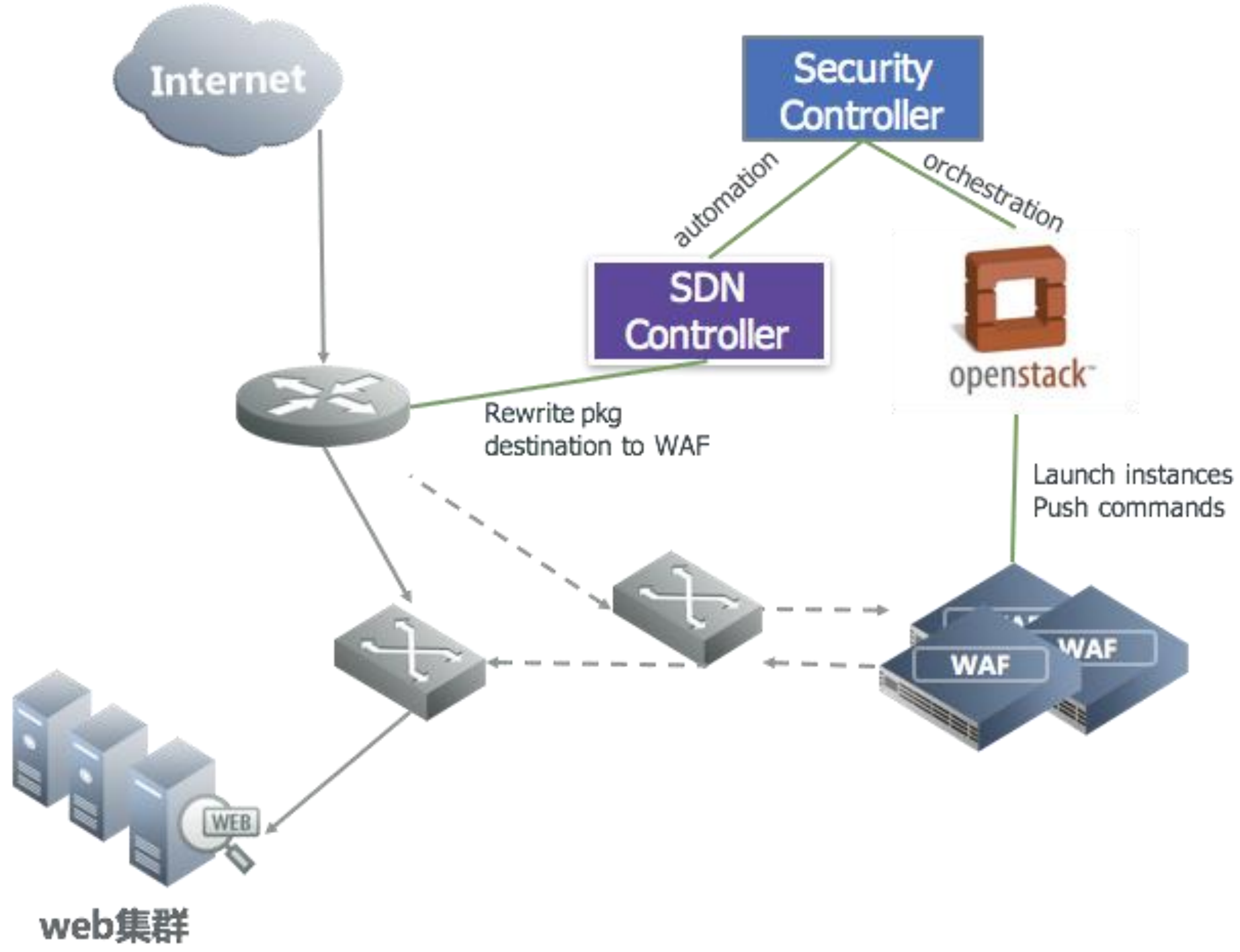


SD-WAN – 中国移动SPTN

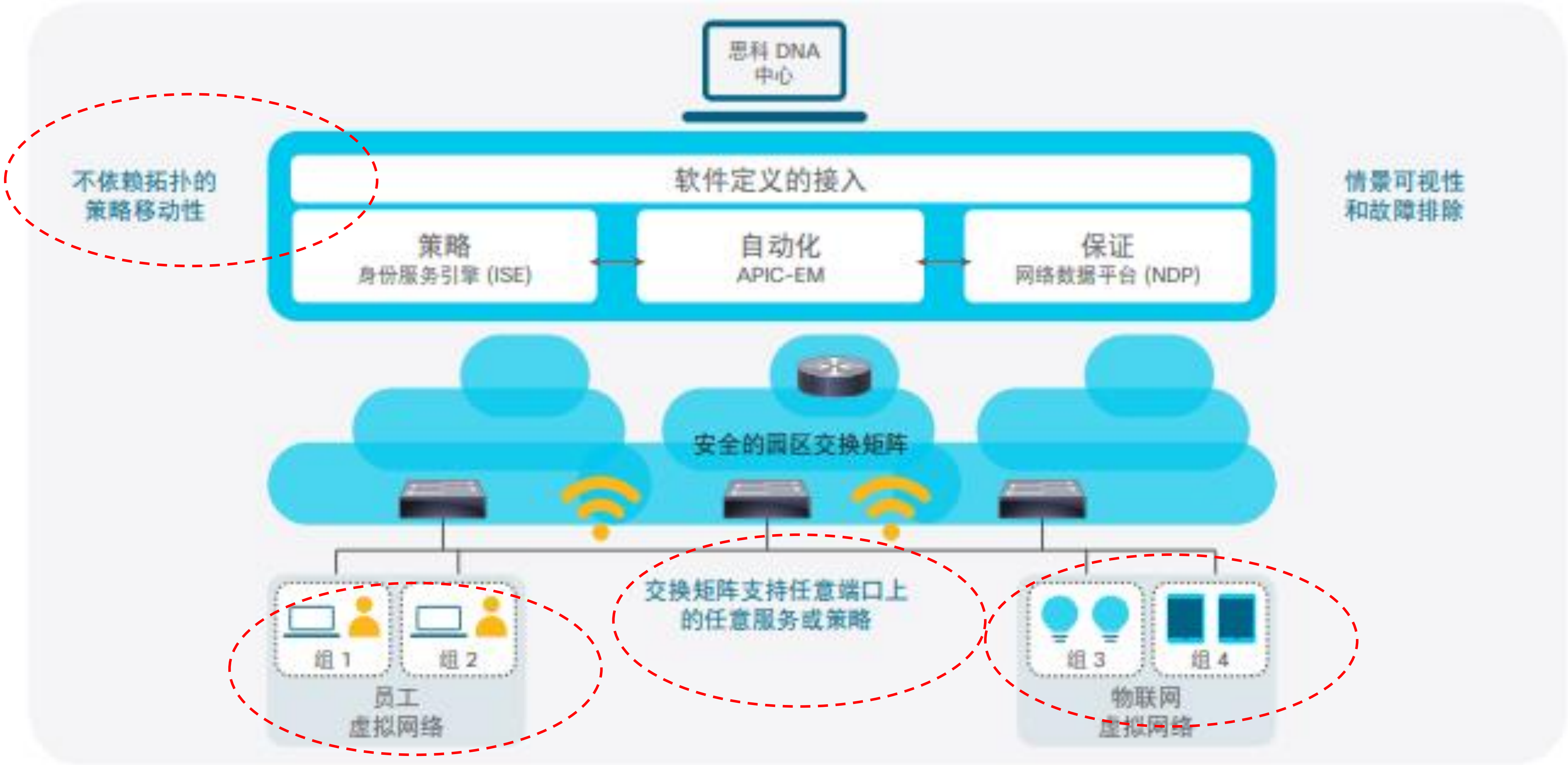
- 保护投资，利用现有传统网络进行上层SDN化；
- 厂商各自基于中国移动提出的北向接口规范开发独立的D-Controller控制器，控制自己的传统设备；
- 中国移动独立自主完成主控制器的S-Controller的开发，利用S-Controller南向接口控制各厂家的D-Controller；
- S-Controller的北向接口提供API实现业务APP的开放接口；



应用场景-安全（SD-Security）



应用场景-接入（SD-Acess）



SDN发展趋势

- 关注热度上升：学术界、产业界
- 应用范围扩大：SD-X（DC、WAN、云&雾、Access ）
- 市场规模快速增长
- 技术融合加速

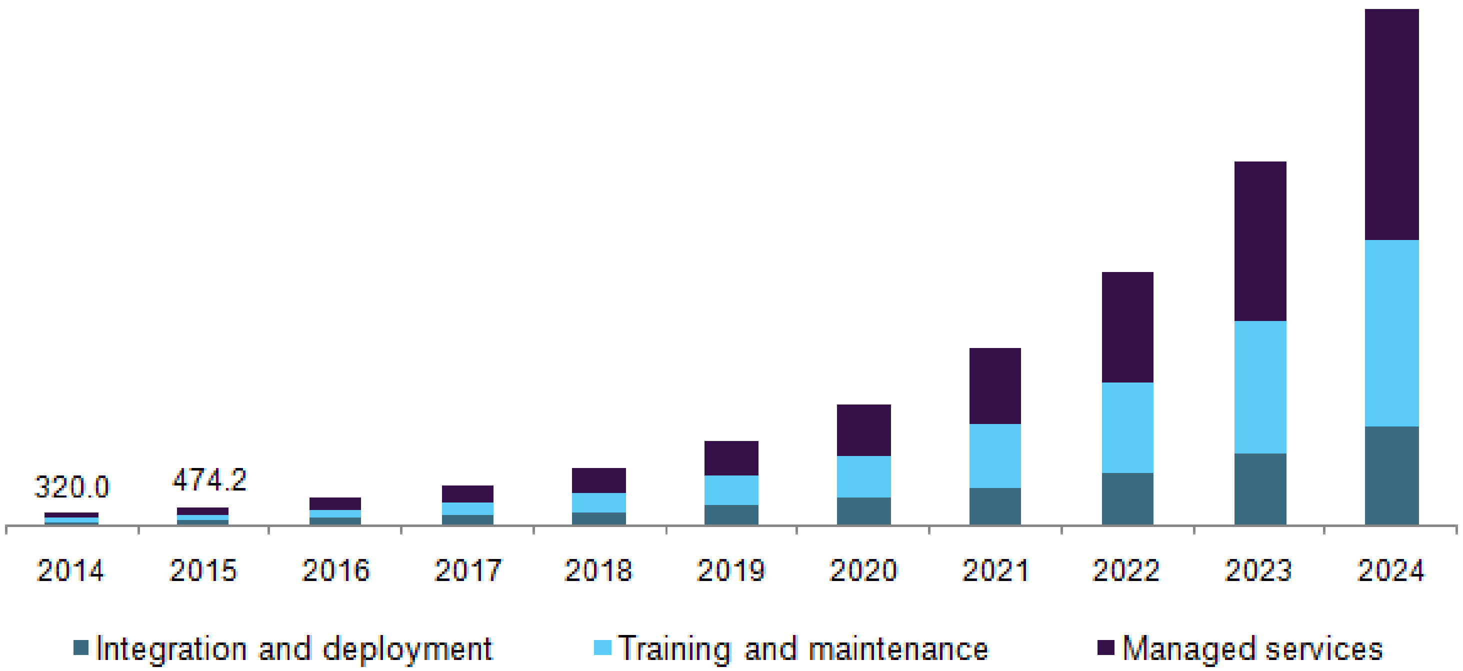
市场占比提升（国内）

相关数据显示：2018年中国 SDN（软件）市场规模达到了 13.9亿元。2019年市场规模将达到 20.5亿元，到 2021年，市场规模将达到 46.7亿元。

图表：未来中国 SDN（软件）市场规模保持高速增长，到 2021年达到 46.7亿元

市场占比提升（国外）

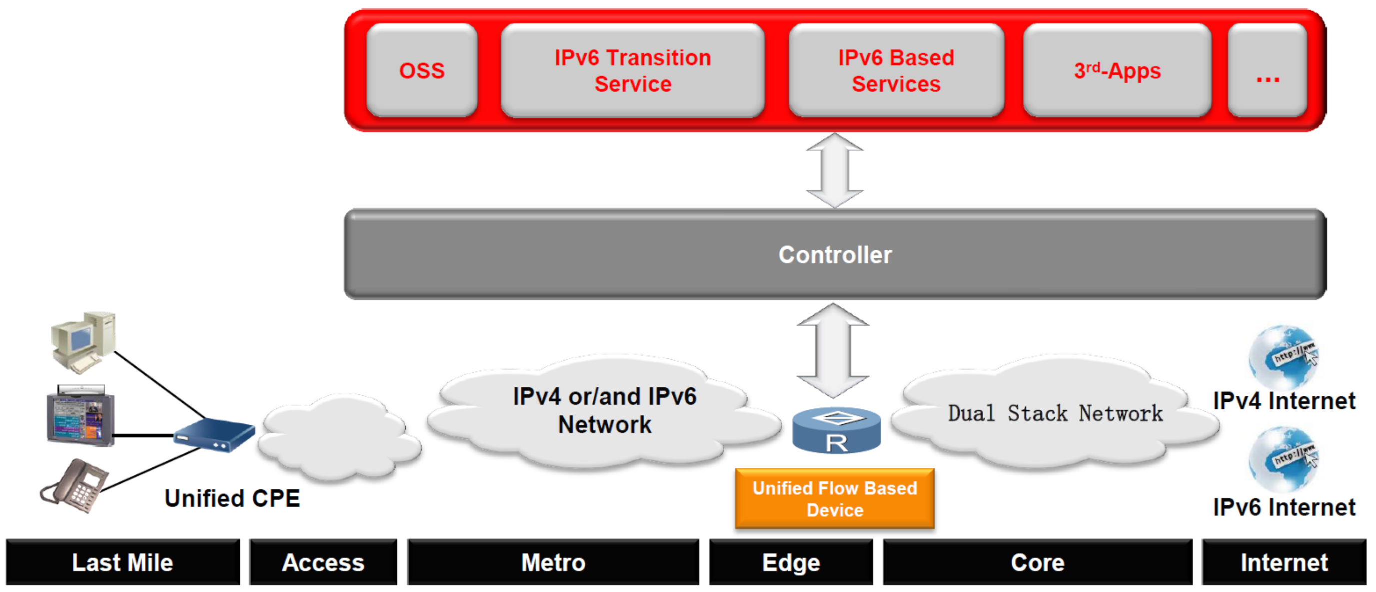
Global software defined networking market, by services, 2014 - 2024 (USD Million)



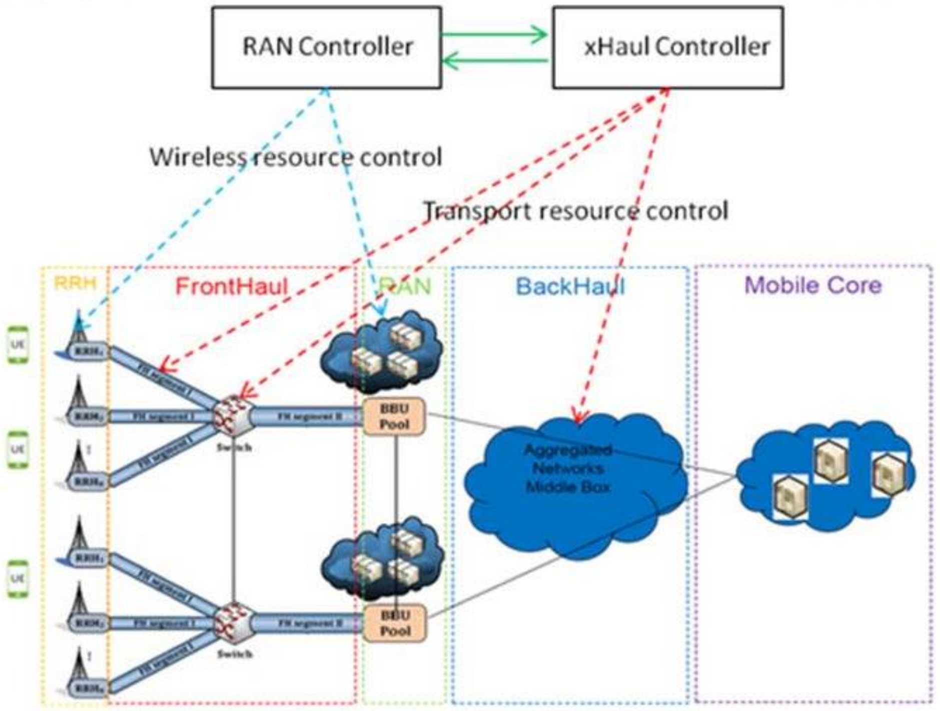
SDN发展趋势

- 关注热度上升：学术界、产业界
- 应用范围扩大：SD-X（DC、WAN、云&雾、Access ）
- 市场规模增长
- 技术融合加速

SDN与IPV6、5G加速融合

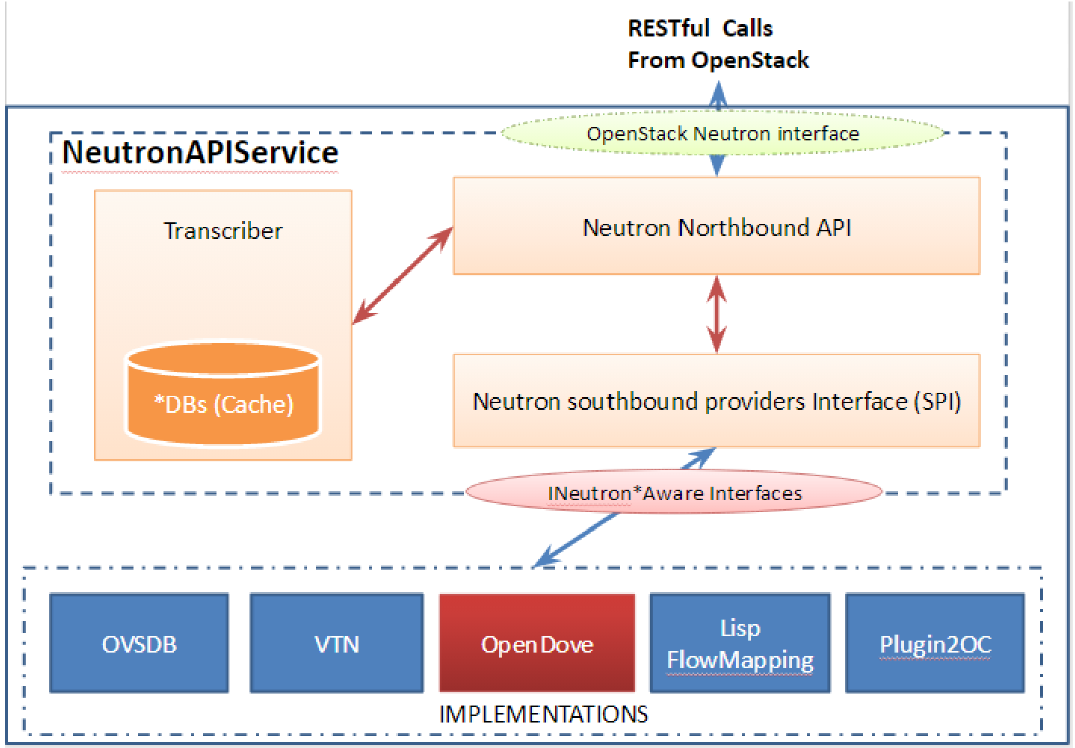


SDN与IPv6技术

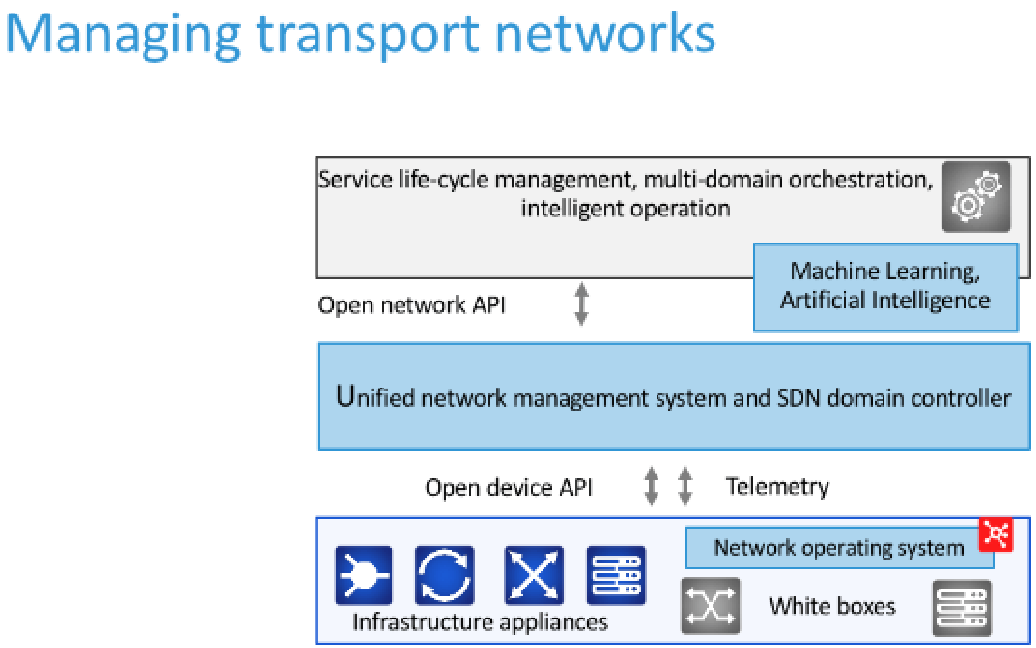


SDN与5G技术

SDN与OpenStack、人工智能加速融合



SDN与OpenStack技术



SDN与人工智能

网络人才新需求

I'm not sure I'd say there is or ever will be a 'SDN engineer' position," says Matthew P. Davy, director of InCNTRE and Indiana University's chief network architect. "But fewer network engineers will be able to live in a world in which they spend 100% of their time using a command line interface [CLI] to configure network appliances. And there will be fewer network engineers who can perform their job while knowing little to nothing about servers, storage, hypervisors, system administratio n and scripting."

谢谢！