SDN, SR, NFV, and MEC

Why SDN and NFV for 5G

In this part of the course we will discuss 4 networking mechanisms :

- **S**oftware **D**efined **N**etworking
- **S**egment **R**outing (which is closely related to SDN)
- **N**etwork **F**unctions **V**irtualization
- **M**obile **E**dge **C**omputing (which is closely related to NFV)

which are widely considered to be essential technologies for 5G

Network slicing is usually considered to require SDN (or Segment Routing)
in order to *dynamically* set up end-to-end paths
that can guarantee the required QoS

The **cloud-native core** and the **disaggregated gNodeB**
will require NFV (or MEC)
in order to instantiate virtual functions

Why SDN and NFV ?

Before explaining ***what*** SDN and NFV are
we need to explain ***why*** SDN and NFV are

Its all started with two related trends ...

1. The blurring of the distinction
between ***computation*** and ***communications***
revealing a fundamental disconnect
between ***software*** and ***networking***

2. The decrease in profitability
of ***traditional communications service providers***
along with the increase in profitability
of **Cloud and Over The Top service providers**

The 1st led directly to SDN
and the 2nd to NFV
but today both are intertwined

1. *Computation* and *communications*

Once there was little overlap
between *communications* (telephone, radio, TV)
and *computation* (computers)

Actually communications devices always ran complex algorithms
but these are hidden from the user

But this dichotomy has become blurred

Most home computers are not used for *computation* at all
rather for entertainment and communications (email, chat, VoIP)

Cellular telephones have become computers

The differentiation can still be seen in the terms *algorithm* and *protocol*

Protocol design is fundamentally harder
since there are two interacting entities (the *interoperability* problem)

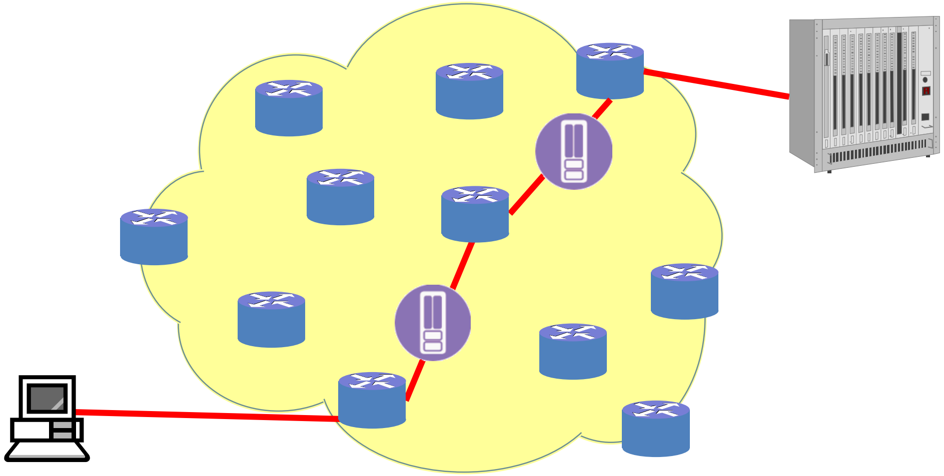
SDN academics claim that packet forwarding is a computation problem
and protocols as we know them should be avoided

1. Rich communications services

Traditional communications services are pure *connectivity* services
- transport data from A to B
  - with constraints (e.g., minimum bandwidth, maximal delay)
  - with maximal efficiency (minimum cost, maximized revenue)

Modern communications services are richer
- combining connectivity and network functionalities
  - e.g., firewall, NAT, load balancing, CDN, parental control, ...

Such services further blur the computation/communications distinction
- and make service deployment optimization more challenging



1. *Software* and *networking speed*

Today, developing a new *iOS/Android* app takes hours to days
but developing a new communications service takes months to years

Even adding new instances of well-known services
is a time consuming process for conventional networks

When a new service types requires new protocols, the timeline is

- protocol standardization (often in more than one SDO)
- hardware development
- interop testing
- vendor marketing campaigns and operator acquisition cycles
- staff training
- deployment

how long has it been since the first IPv6 RFC ?

This leads to a *fundamental disconnect*
between software and networking development timescales

An important goal of SDN and NFV is
to create new network functionalities at the *speed of software*

2. Today's communications world

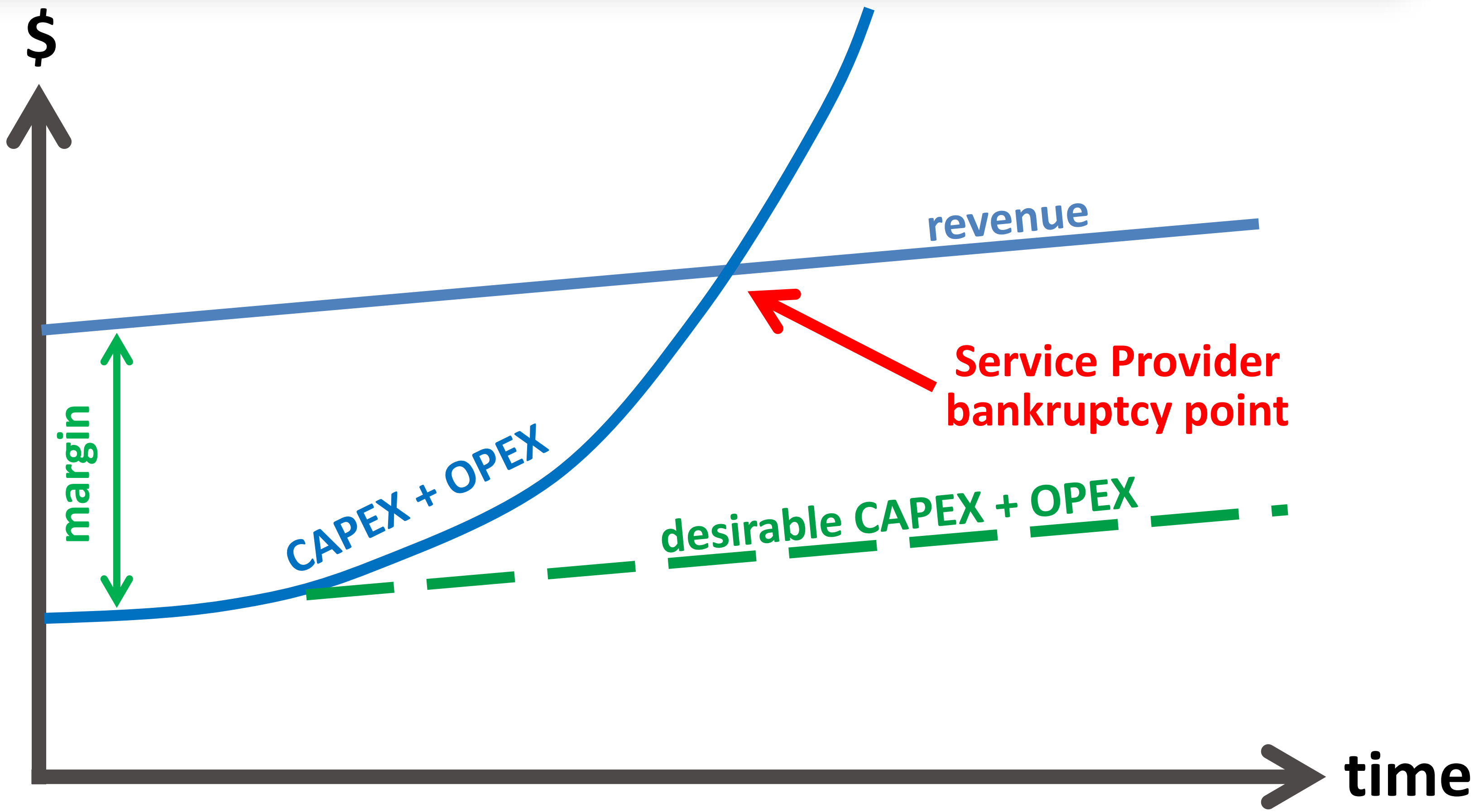
Today's infrastructures are composed of many different Network Elements (NEs)

- sensors, smartphones, notebooks, laptops, desk computers, servers,
- DSL modems, Fiber transceivers,
- SONET/SDH ADMs, OTN switches, ROADMs,
- Ethernet switches, IP routers, MPLS LSRs, BRAS, SGSN/GGSN,
- NATs, Firewalls, IDS, CDN, WAN aceleration, DPI,
- VoIP gateways, IP-PBXes, video streamers,
- performance monitoring probes , performance enhancement middleboxes,
- etc., etc., etc.

New and ever more complex NEs are being invented all the time,
and while equipment vendors like it that way
Service Providers find it hard to shelve and power them all !

In addition, while service innovation is accelerating
the increasing sophistication of new services
the requirement for backward compatibility
and the increasing number of different SDOs, consortia, and industry groups
which means that
it has become very hard to experiment with new networking ideas
NEs are taking longer to standardize, design, acquire, and learn how to operate
NEs are becoming more complex and expensive to maintain

2. The service provider crisis



This is a *qualitative* picture of the service provider's world
Revenue is at best increasing with number of users
Expenses are proportional to bandwidth – doubling every 9 months
This situation obviously can not continue forever !

Two complementary solutions

Software Defined Networks (SDN)

SDN advocates replacing standardized networking protocols
with centralized software applications
that configure all the NEs in the network

Advantages:

- easy to experiment with new ideas
- control software development is much faster than protocol standardization
- centralized control enables stronger optimization
- functionality may be speedily deployed, relocated, and upgraded

Network Functions Virtualization (NFV)

NFV advocates replacing hardware network elements
with software running on COTS computers
that may be housed in POPs and/or datacenters

Advantages:

- COTS server price and availability scales with end-user equipment
- functionality can be located where-ever most effective or inexpensive
- functionalities may be speedily combined, deployed, relocated, and upgraded

SDN

Abstractions

SDN was triggered by the development of networking technologies
not keeping up with the speed of software application development

Computer science theorists theorized
that this derived from not having the required **abstractions**

In CS an *abstraction* is a representation
that reveals semantics needed *at a given level*
while hiding implementation details
thus allowing a programmer to focus on necessary concepts
without getting bogged down in unnecessary details

Programming is fast because programmers exploit abstractions

Example:

It is very slow to code directly in assembly language (with few abstractions, e.g. opcode mnemonics)
It is a bit faster to coding in a low-level language like C (additional abstractions : variables, structures)
It is much faster coding in high-level imperative language like Python
It is much faster yet coding in a declarative language (coding has been abstracted away)
It is fastest coding in a domain-specific language (only contains the needed abstractions)
In contrast, in protocol design we return to *bit level* descriptions every time

Packet forwarding abstraction

The first abstraction relates to how network elements forward packets

At a high enough level of abstraction
all network elements perform the same task

Abstraction 1 *Packet forwarding as a computational problem*
The function of any network element (NE) is to
- receive a packet
- observe packet fields
- apply algorithms (classification, decision logic)
- optionally edit the packet
- forward or discard the packet

For example

- An Ethernet switch observes MAC DA and VLAN tags, performs exact match, forwards the packet
- A router observes IP DA, performs LPM, updates TTL, forwards packet
- A firewall observes multiple fields, performs regular expression match, optionally discards packet

We can replace all of these NEs with a configurable ***whitebox switch***

Network state and graph algorithms

How does a whitebox switch learn its required functionality ?

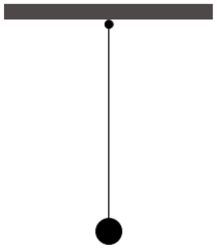
Forwarding decisions are optimal
when they are based on full global knowledge of the network

With full knowledge of topology and constraints
the path computation problem can be solved by a graph algorithm

While it may sometimes be possible to perform path computation (e.g., Dijkstra)
in a distributed manner
It makes more sense to perform them centrally

Abstraction 2 *Routing as a computational problem*
Replace distributed routing protocols with graph algorithms
performed at a central location

Note with SDN, the pendulum that swung
from the completely centralized PSTN
to the completely distributed Internet
swings back to completely centralized control



Configuring the whitebox switch

How does a whitebox switch acquire the information needed to forward
that has been computed by an omniscient entity at a central location ?

Abstraction 3 *Configuration*
Whitebox switches are directly *configured* by an *SDN controller*

Conventional network elements have two parts:

1. smart but slow CPUs that create a Forwarding Information Base
2. fast but dumb switch fabrics that use the FIB

Whitebox switches only need the dumb part, thus

- eliminating distributed protocols
- not requiring intelligence

The API from the SDN controller down to the whitebox switches
is conventionally called the *southbound API* (e.g., OpenFlow, ForCES)

Note that this SB API is in fact a *protocol*
but is a simple configuration protocol
not a distributed routing protocol

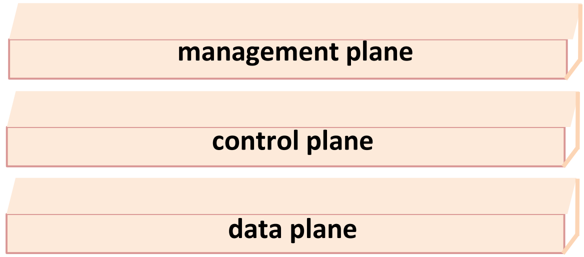
Separation of data and control

You will often hear stated that the *defining attribute* of *SDN* is the separation of the *data* and *control* planes

This separation was not invented recently by SDN academics
Since the 1980s all well-designed communications systems have enforced logical separation of 3 planes :

- data plane (forwarding)
- control plane (e.g., routing)
- management plane (e.g., policy, commissioning, billing)

What SDN really does is to
1) insist on ***physical*** separation of data and control
2) erase the difference between control and management planes



Flows

It would be too slow for a whitebox switch
to query the centralized SDN controller
for every packet received

So we identify packets as belonging to **flows**

Abstraction 4 *Flows* (as in Open**Flow**)
Packets are handled solely based on the flow to which they belong

Flows are thus just like **F**orwarding **E**quivalence **C**lasses

Thus a flow may be determined by
- an IP prefix in an IP network
- a label in an MPLS network
- VLANs in VLAN cross-connect networks

The granularity of a flow depends on the application

Control plane abstraction

In the standard SDN architecture, the SDN controller is omniscient
but does not itself *program* the network
since that would limit development of new network functionalities

With software we create building blocks with defined APIs
which are then used, and perhaps inherited and extended, by programmers

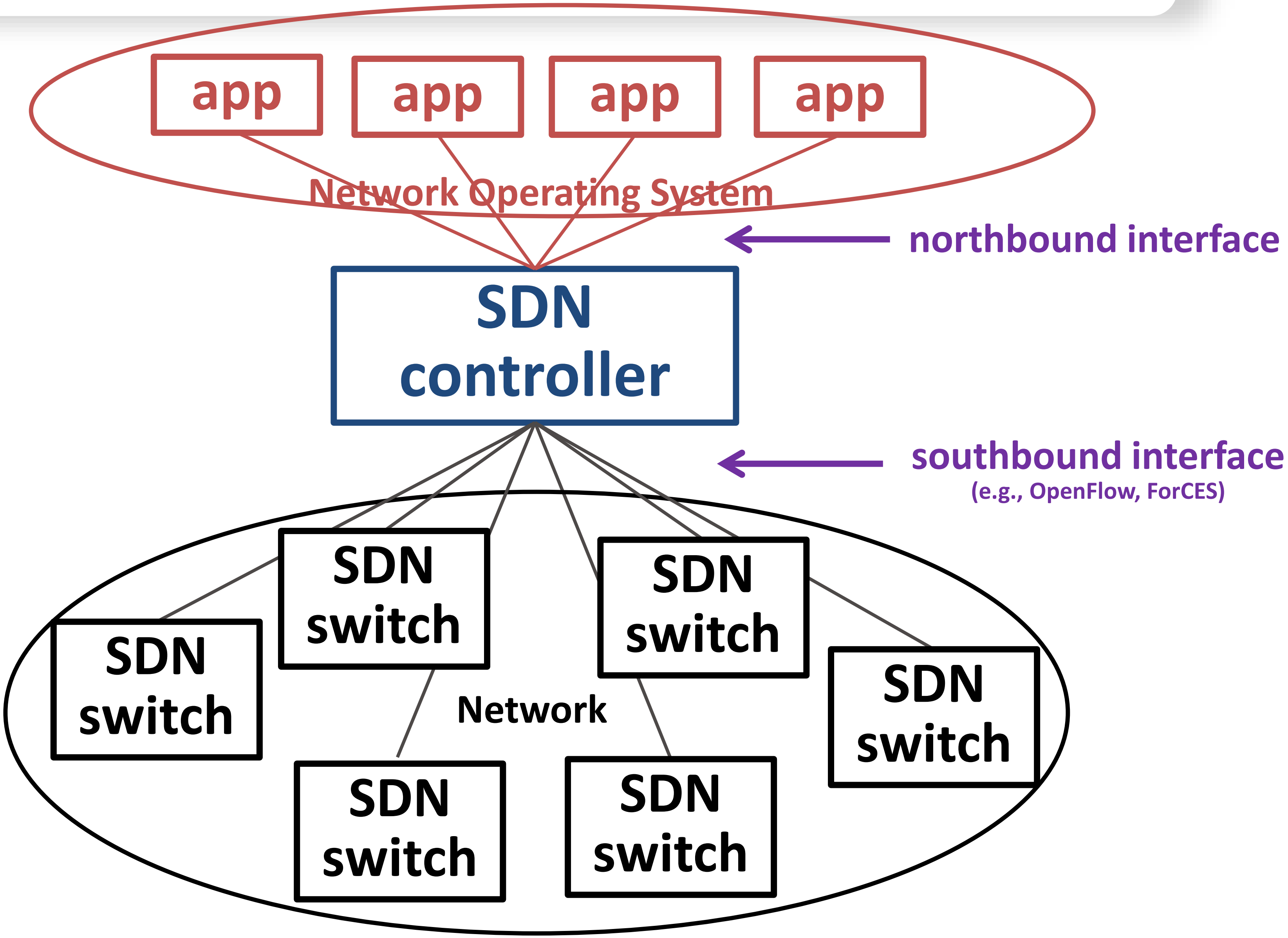
With networking, each network *application* has a tailored-made control plane
with its own element discovery, state distribution, failure recovery, etc.

Note the subtle change of terminology we have just introduced
instead of calling switching, routing, load balancing, etc. network *functions*
we call them network *applications* (similar to software *apps*)

Abstraction 5 Northbound *APIs instead of protocols*
Replace control plane protocols with well-defined APIs to network applications

This abstraction hide details of the network from the network application
revealing high-level concepts, such as requesting connectivity between A and B
but hiding details unimportant to the application
such as details of switches through which the path A → B passes

SDN overall architecture



Segment Routing

Source routing

IP routing is based on destination addresses (and perhaps DSCP)
but sometimes we need control over
the precise path a packet travels to its destination

For example

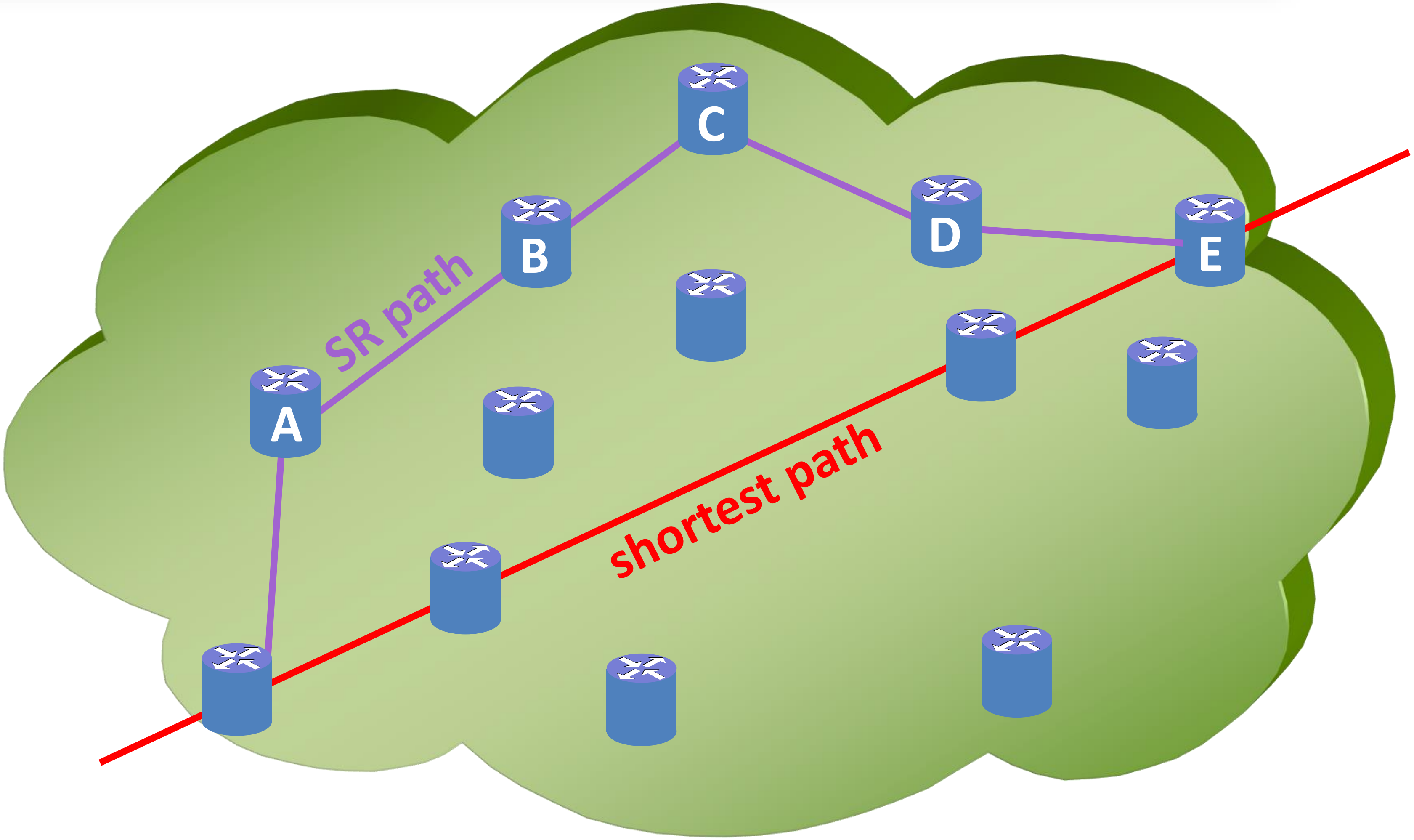
- in DCs we need to ensure packets traverse nodes (in order)
- for security we may need to avoid a particular router
- *policy-based routing* enables overriding default routing
- we may need paths with special characteristics (e.g., low delay)

IP protocols provide mechanisms called **S**ource **R**outing

- IPv4 source routing options (Loose SR, Strict SR)
- IPv6 type 0 routing header extension (Rh0)

Source Routing inserts sequences of router addresses
into packet headers

Source routing example



Loose SR – A C D
Strict SR – A B C D E

Source routing is evil

Yet source routing is now considered *evil*, because

- overly complicated processing for core routers
- DoS attack – attacker forces packets to traverse selected routers, thus overloading them
- amplified DoS attack – attacker forces packet to oscillate between 2 selected routers
- infiltration attack – attacker bypasses ACLs by forwarding through a permitted waypoint

The IETF has not yet completely deprecated source routing but highly recommends that it be disabled

Core Internet routers typicallt drop packets with options

Linux kernels no longer process Source Routing

Safe policy-based routing

But without SR, how can we achieve policy based routing?

There are 2 alternatives

Standard **S**oftware **D**efined **N**etworking

SDN gives the network administer full control over routing

particular flows can be *configured* to traverse arbitrary paths

But SDN

- requires relatively large architectural changes
- requires significant state to be stored in the network
- requires multiple "touches" to the on-path network elements
- enables attacks (and plain bugs) at control plane level

Segment Routing

Segment routing is similar to Source Routing, **but**

the path is specified by an *ingress router*, not by the *source host*

thus blocking Source Routing attacks (unless a router is compromised)

Segment routing vs. standard SDN

In SDN the *network* maintains per-application/flow state
With SR forwarding instructions are provided in the *packet*

In SDN all the intelligence is in the centralized controller
- the SDN switches are dumb, fast, and inexpensive

SR burdens the ingress LER (like PCE)
- it needs to digest the IGP, prepare the label stack, ...

OpenFlow-based SDN has a major design flaw
- flows are identified by configuring matching tables
- matching table logic for 1 flow may influence other flows
- so even minor bugs, and certainly malicious rules
  - may impact services that have been running perfectly for years

Errors in Segment Routing only affect the flow itself

Both SR and SDN can coexist with conventional networking

Segment Routing encapsulations

Segment Routing works by inserting a Segment Routing Header (SRH)
consisting of a list of Segment Identifiers (SIDs)

Segments are actually forwarding instructions (more on that later)

SR enforces a flow path while maintaining state only at the ingress node

SR was originally designed for MPLS networks
which natively employ a *label stack*

- existing MPLS LSRs support the SR-MPLS user plane (if they support long stacks)
- a minor control-plane upgrade is needed

SR is also defined for IPv6 (but not for IPv4) where it is called SRv6

- SRv6 requires routers to support a new IPv6 extension header

A third encapsulation transports SR-MPLS inside UDP/IP

MPLS-based Segment Routing

MPLS forwards packets using a simple universal paradigm

- read ToS Label
- look up label in LFIB
- perform label stack operation (swap, push, pop) in NHLFE
- forward packet according to NHLFE

In *regular* MPLS networks

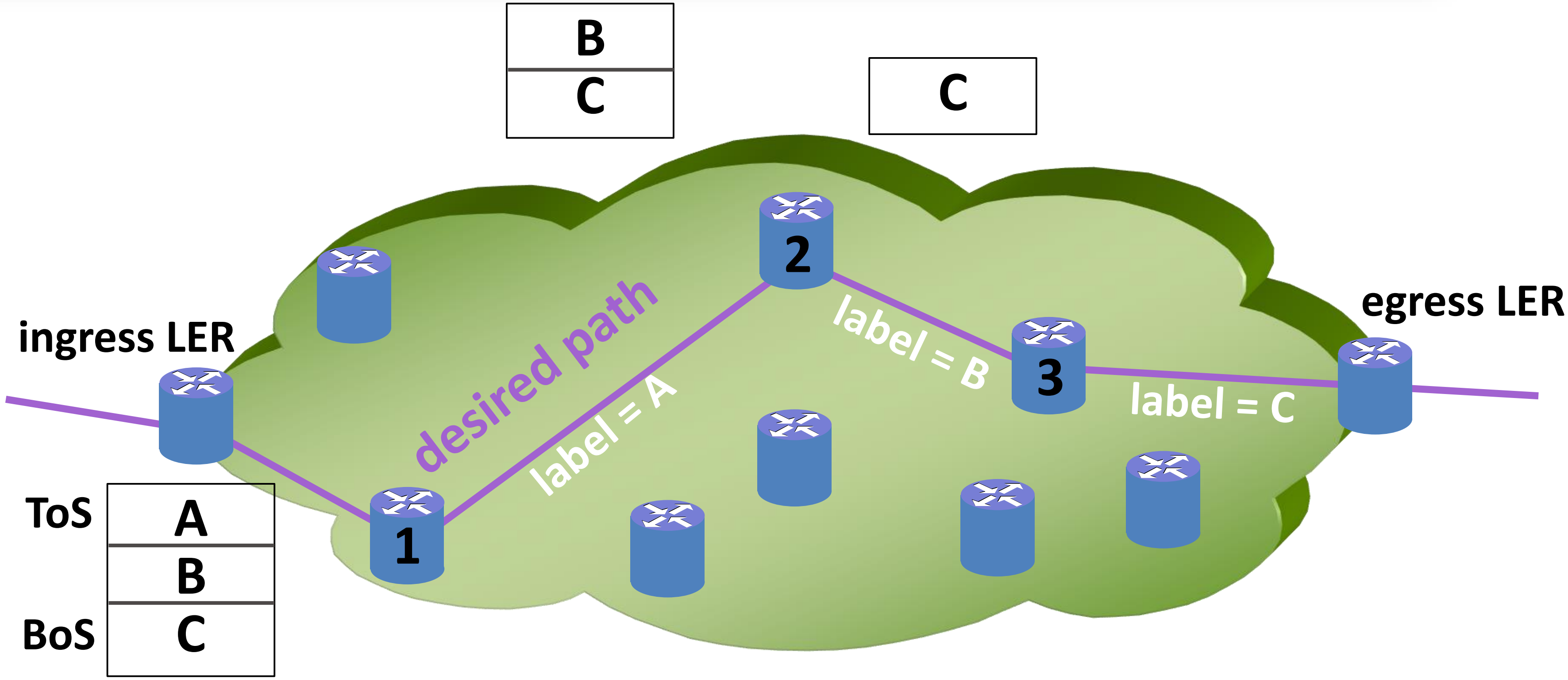
- most of the time the label stack operation is swap
- pop is used by egress LERs and FRR

MPLS segment routing *reuses* the standard MPLS mechanism

- ingress LER inserts an entire stack of labels, one per hop
- each LSR pops a label revealing the next hop

MPLS SR doesn't require LDP or RSVP-TE (but extends the IGP)

MPLS Segment Routing example



Ingress LER inserts label stack with 3 labels : A (ToS), B, C (BoS)

- 1st LSR reads A, pops label, forwards over link for A
- 2nd LSR reads B, pops label, forwards over link for B
- 3rd LSR reads C, pops label, forwards over link for C

Global and local segments

In Segment Routing the labels are called *Segment IDs* (SIDs)
- in *MPLS* SR the SID is the 20-bit label
- and in *IPv6* SR (SRv6) it is a 128-bit address

There are 2 main types of SIDs :

An **adjacency SID** (local SID) refers to a link (port)
- it has local significance (like normal MPLS labels)
- only the LSR advertising it can use it with that meaning

A **node SID** (prefix SID, global SID) refers to a destination node
- if has global significance (unique, like IP addresses)
- the network forwards over the shortest path to the node
- every LSR has the same entry in its LFIB

WARNING: this is a simplification

Label distribution

The ingress LER learns *nodes* and *adjacencies*
from the **I**nterior **G**ateway **P**rotocol (e.g., OSPF or IS-IS)

Hence, it can select each node and link
to be traversed along the desired path

The source LSR can insert
(global) node SIDs (either direct or loose)
or adjacency SIDs
or combinations

But how does the source LSR know the labels
that indicates to an LSR to forward over a desired link?

Segment Routing augments the IGP with label information
(LDP, used in *vanilla MPLS*, is no longer needed)

Segments as programming instructions

Constructing a segment routing label stack
is similar to programming in a low-level language
so the SR can be used for *network programming*

Each label can be considered to be an instruction (op-code)

The ingress LER encodes the list of instructions (SIDs)
and each LSR interprets and executes one instruction
thus making the networking into a giant processor

Segment instructions can be:

- Forward over link L
- Go to node N using the shortest path
- Apply service (function) S

so that SR can specify a chain of VNFs
obviating the need for **N**etwork **S**ervice **H**eaders

IPv6 extension headers

The standard IPv6 header looks like this:

VER=6	TC 8b	Flow label 20b
Payload Length 16b	Next Header 8b	Hop Limit 8b
Source Address (SA) 128 bits		
Destination Address (DA) 128 bits		

and by using "Next Header" one can add options

Next Header 8b	Header Len 8b	options + padding
options + padding		

in particular, the routing extension header

Next Header 8b	Header Len 8b	Type 8b	Segments Left 8b
optional type-specific data			

SRv6 extension header (SRH)

SRv6 uses the routing extension header with type = 4
and multiple SRv6 segments are concatenated

Next Header 8b	Header Len 8b	Type=4 8b	Segments Left 8b
Last Entry 8b	Flags 8b	Tag	
Segment[0] 128b			
Segment[1] 128b			
…			
Segment[n] 128b			
optional TLVs			

Next Header identifies the type of header after the SRH
Segments Left is decremented at each segment
Last Entry = n (the last entry in the segment list)
Flags include P (protected) O (OAM) A (Alert) and H (HMAC)

Header size ≥ 8 + $16N_{seg}$ Bytes

Unified-IP-SR

There is another encapsulation for SR in IP networks

RFC 7510 defines MPLS-in-UDP for IPv4 or IPv6 networks

This encapsulation may be better than RFC 4023 **MPLS-in-IP** **MPLS-in-GRE-in-IP**

since it enables fine grain load balancing using ECMP for IPv4

by using the UDP port for entropy (IPv6 already has the flow label)

Unified-IP-SR exploits MPLS-in-UDP to carry MPLS SR

Routers must be capable of this new type of forwarding

and must advertise this capability in the IGP

but Unified-IP-SR can function

with a mixture of unified-IP-SR capable and legacy routers

TI-LFA

One of the deficiencies of standard SDN is the lack of resilience
OpenFlow provides a mechanism via group tables

Segment routing enables a new resilience method that
- do not require signaling
- do not require maintaining massive network state
- avoid looping

called **T**opology **I**ndependent **L**oop **F**ree **A**lternatives – TI-LFA

Topology Independence means that a loop free backup is found
irrespective of the topologies before and after the failure

Immediately upon discovering the failure
the source router uses the new SR segment list
so the protection switch time is minimal

NFV

Virtualization of computation

In the field of computation, there has been a major trend towards ***virtualization***

Virtualization here means the creation of a **virtual machine** (VM)
that acts like an independent physical computer

A **VM** is software that emulates hardware (e.g., an x86 CPU)
over which one can run software as if it is running on a physical computer

The VM runs on a *host* machine
and creates a *guest* machine (e.g., an x86 environment)

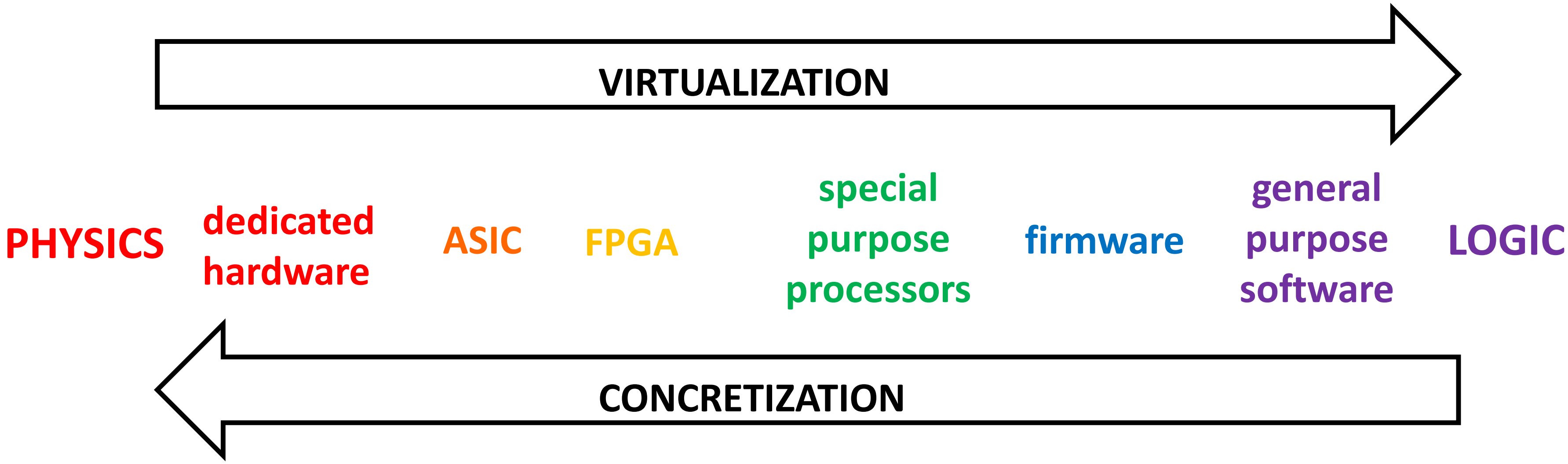
A single host computer may host many fully independent guest VMs
and each VM may run different Operating Systems and/or applications

For example

- a datacenter may have many racks of server cards
- each server card may have many (host) CPUs
- each CPU may run many (guest) VMs

A **hypervisor** is software that enables *creation* and *monitoring* of VMs

Concretization and Virtualization



Concretization means moving a task *to the left*

Justifications for concretization include :

- cost savings for mass produced products
- miniaturization/packaging constraints
- need for high processing rates
- energy savings / power limitation / low heat dissipation

Virtualization is the opposite - moving a task *to the right*

(although frequently reserved for the extreme case of HW → SW)

Network Functions Virtualization

CPUs are not the only hardware device that can be virtualized

Many (but not all) NEs can be replaced by software running on a CPU or VM

This would enable

- using standard COTS hardware (whitebox servers)
  - reducing CAPEX and OPEX
- fully implementing functionality in software
  - reducing development and deployment cycle times, opening up the R&D market
- consolidating equipment types
  - reducing power consumption
- optionally concentrating network functions in datacenters or POPs
  - obtaining further economies of scale. Enabling rapid scale-up and scale-down

For example, switches, routers, NATs, firewalls, IDS, etc.
are all good candidates for virtualization
as long as the data rates are not too high

Physical layer functions (e.g., Software Defined Radio) are not ideal candidates

High data-rate (core) NEs will probably remain in dedicated hardware

Function relocation

Once a network functionality has been virtualized
it is relatively easy to relocate it

By relocation we mean
placing a function somewhere other than its conventional location
e.g., at **P**oints **o**f **P**resence and **D**ata **C**enters

Many (mistakenly) believe that the main reason for NFV
is to move networking functions to data centers
where one can benefit from economies of scale

Some telecomm functionalities need to reside at their conventional location

- Loopback testing
- E2E performance monitoring

but many don't

- routing and path computation
- billing/charging
- traffic management
- DoS attack blocking

Note: even nonvirtualized functions *can* be relocated

Example of relocation with SDN

SDN is, in fact, a specific example of function relocation

In conventional IP networks routers perform 2 functions

- forwarding
  - observing the packet header
  - consulting the **F**orwarding **I**nformation **B**ase
  - forwarding the packet
- routing
  - communicating with neighboring routers to discover topology (routing protocols)
  - runs routing algorithms (e.g., Dijkstra)
  - populating the FIB used in packet forwarding

SDN enables moving the routing algorithms to a centralized location

- replace the router with a simpler but configurable whitebox switch
- install a centralized SDN controller
  - runs the routing algorithms (internally – w/o on-the-wire protocols)
  - configures the NEs by populating the FIB

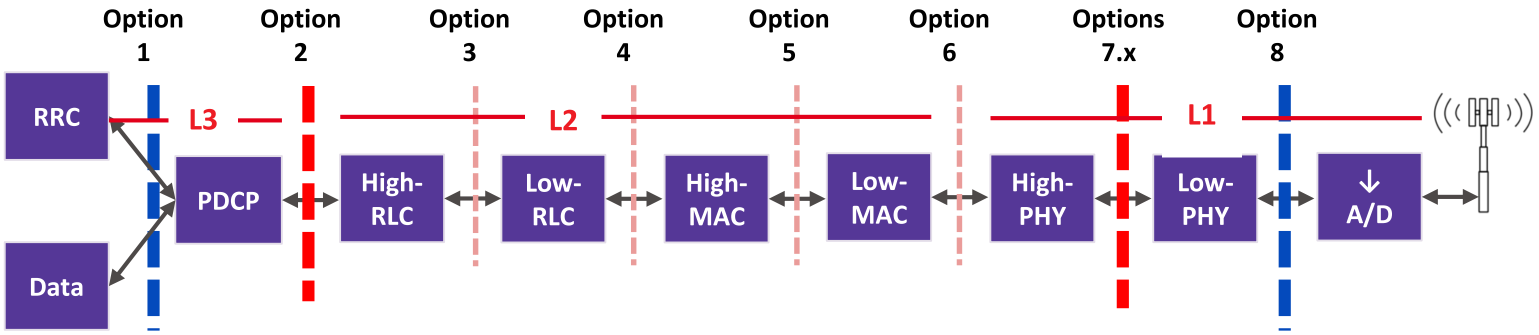
Micro-services

When building physical networks elements
  there is pressure to put all functionality into a single box

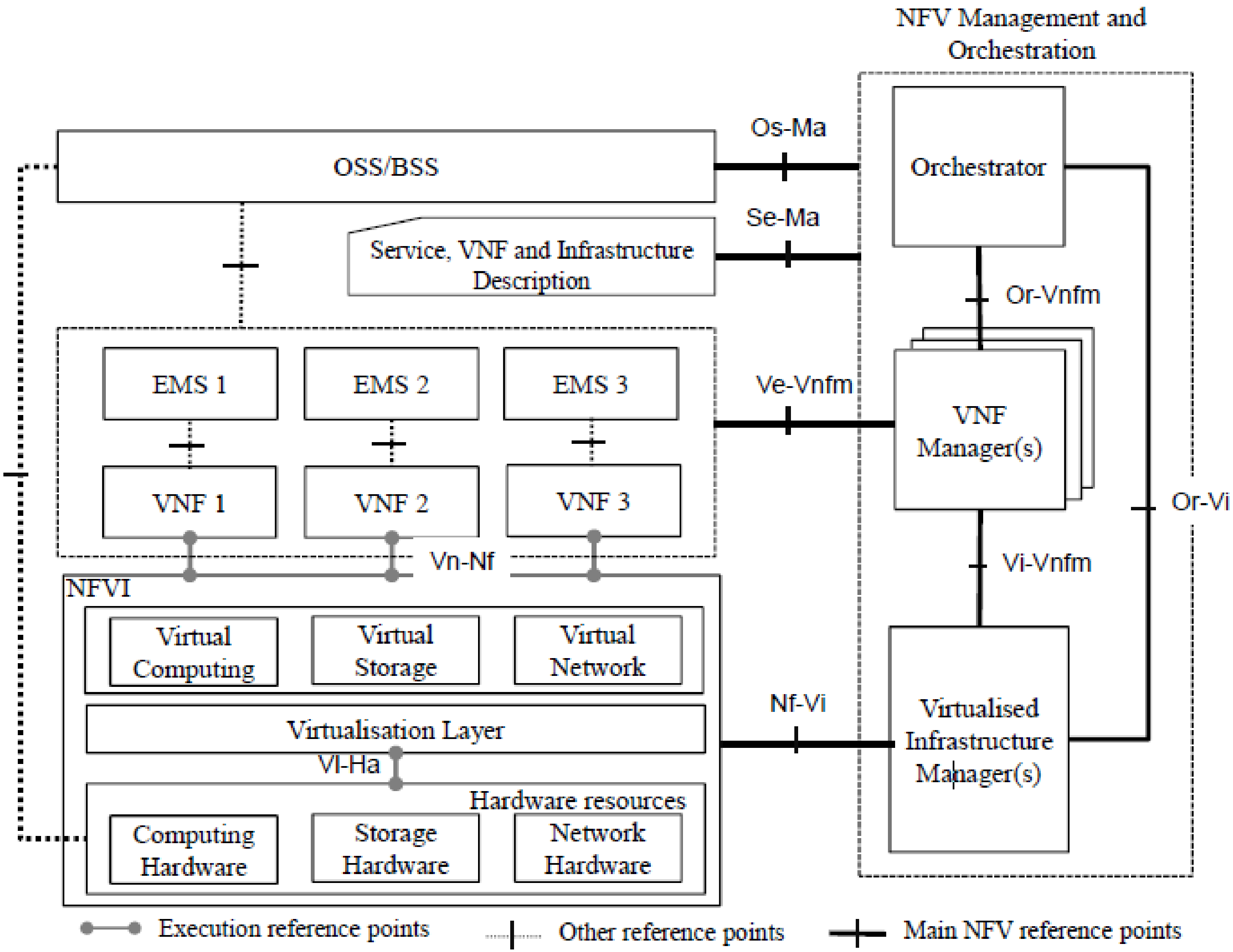
Modern software systems are designed to be flexible
  by using *micro-services* and *function chaining*

For example, many network functions utilize (deep) packet inspection
  but this function is not packaged separately as a micro-service

The functional decomposition of a gNB that we have seen before
  can be seen to be a chain of micro-services
  many of which can be virtualized



ETSI NFV-ISG architecture



MANO ? VIM ? VNFM? NFVO?

Traditional NEs have NMS (EMS) and perhaps are supported by an OSS

NFV has *in addition* the MANO (Management and Orchestration) containing :

- an orchestrator
- VNFM(s) (VNF Manager)
- VIM(s) (Virtual Infrastructure Manager)
- lots of reference points (*interfaces*) !

The VIM (usually OpenStack) manages NFVI resources in one NFVI domain

- life-cycle of virtual resources (e.g., set-up, maintenance, tear-down of VMs)
- inventory of VMs
- FM and PM of hardware and software resources
- exposes APIs to other managers

The VNFM manages VNFs in one VNF domain

- life-cycle of VNFs (e.g., set-up, maintenance, tear-down of VNF instances)
- inventory of VNFs
- FM and PM of VNFs

The NFVO is responsible for resource and service orchestration

- controls NFVI resources everywhere via VIMs
- creates end-to-end services via VNFMs

MEC

Origin of MEC

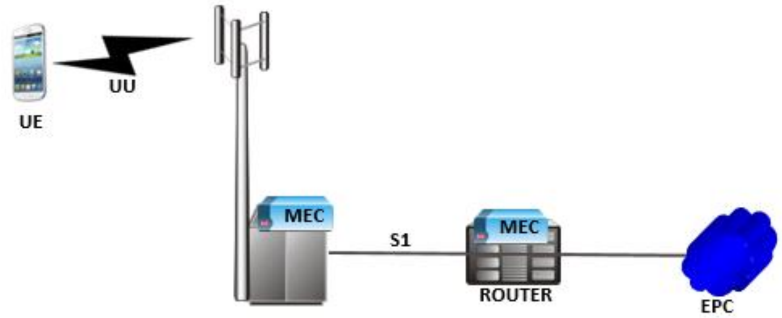
2012 a group of service providers created ETSI NFV ISG to promote virtualization of network functions (mostly relocating them to data centers)

2013 RAD proposed Distributed NFV (DNVF) – hosting VNFs in a CPE

2013 NSN introduced Liquid apps – a Radio Applications Cloud Server (RACS) capable of running VNFs in base stations

2014 a group of companies created ETSI MEC (Mobile Edge Computing) ISG

During its work, MEC was generalized the concept of edge from the base station to include a PoP in the RAN



2016 MEC was renamed Multi-access Edge Computing to include edge computing in the wireline case

Why do we need local processing?

Both uCPE and MEC hinge on processing
that needs to be performed locally
rather than relocated to a remote data center

What leads to the need for local processing ?

- Functionalities that are *required* to be local (FM, PM, encryption, etc.)
- Applications that require ultra-low delay (e.g., URLLC)
- Functions that perform best when local (e.g., interactive)
- Persistent local storage
- Access to local resources (not available to OTT services)
- Reduce requirements for high bandwidth for long distances
  thus reducing congestion
- Keep local data local

MEC Use Cases

MEC ISG identified numerous applications
wherein mobile networks require local processing or storage:

- Enterprise services including VoLTE and breakout to enterprise LAN
- Live video streaming
- Identity based content delivery
- Location based content delivery (retail, consumer, ...)
- Location tracking
- RAN/application aware content optimization
- Distributed content and DNS caching
- AR (location based) / VR including real-time streaming
- Video acceleration and analytics
- IoT detection/processing/aggregation
- V2x (ultra low delay)
- Emergency response / law enforcement

Required mobile services

MEC facilitates hosting third-party applications in mobile networks

From the use cases one can discern the requirement
for access to certain services from the mobile network, including:

- traffic steering (based on application, user, location, etc.) both between MEC applications and to/from network
- local persistent storage
- traffic rule enforcement
- local DNS proxy/server
- UE identification (e.g., the IMSI)
- Radio Network Information Services (cell identifier, handoff occurred, etc.)
- Location (geolocation coordinates)
- Traffic prioritization and bandwidth policy enforcement
- Lawful interception and metadata retention

Much of the MEC ISG's work focused on defining APIs
for MEC applications to access these services

MEC platform

As part of the *MEC host* server hosting the *MEC applications*
MEC defines a *MEC platform* supporting modern cloud methods

The MEC platform enables MEC applications to:

- discover available services
- consume services
- advertise services that the application can provide

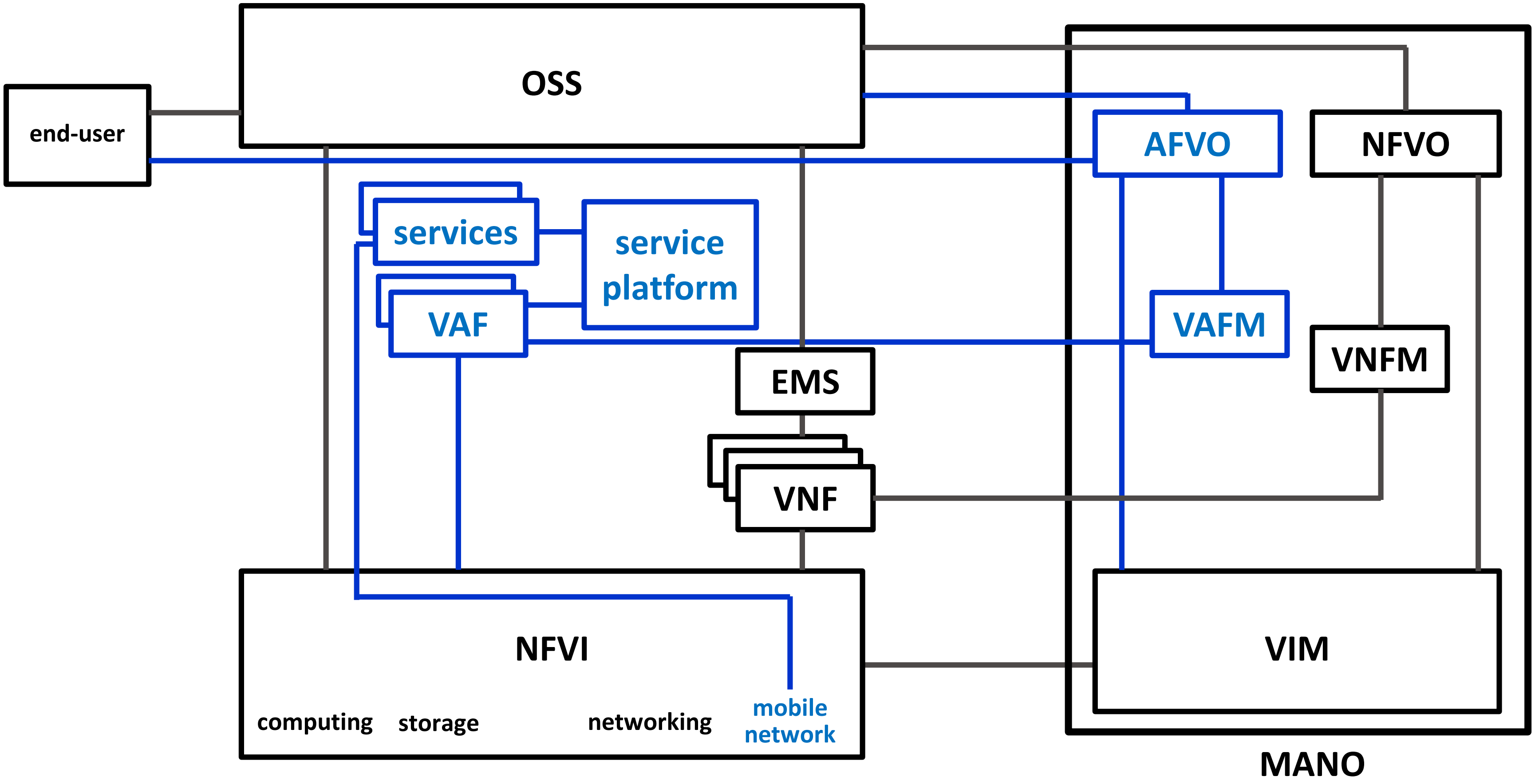
It is also responsible for

- steering traffic between chained applications
- apply traffic forwarding rules
- configure forwarding plane and DNS based on policies
  this includes using DNS proxy to direct user traffic to MEC application

We will see (when studying the 5G core)
that 5G's **S**ervice **B**ased **A**rchitecture learned from MEC principles
and in particular provides a **N**etwork **E**xposure **F**unction

An NFV approach

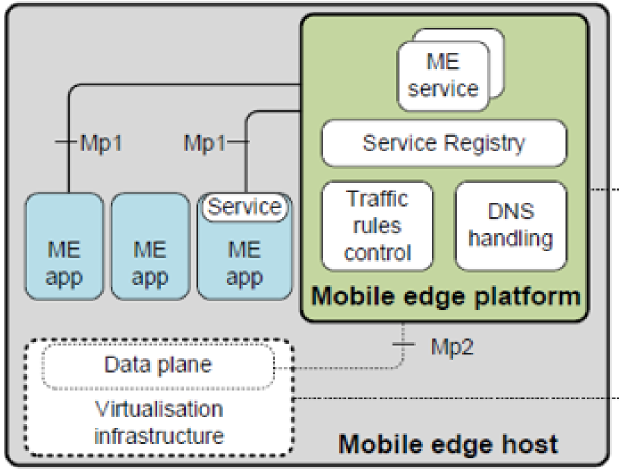
One could envision MEC as an extension to the standard NFV model



Mobile edge host

The Mobile edge host is composed of:

- the NFVI
  - server
  - virtualization
  - persistent storage
  - networking software and hardware
  - time-of-day clock
- the mobile edge applications and services
- the mobile edge platform (already discussed)

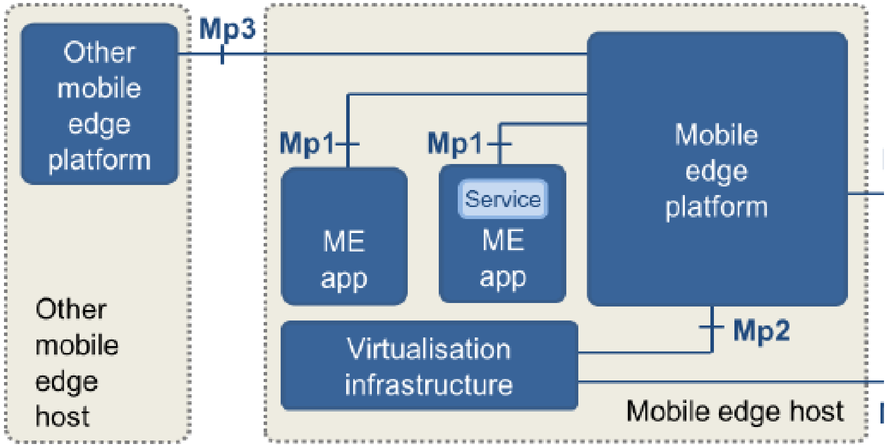


Mobile Edge Platform (MEP)

The ME platform includes baseline functionalities needed to ME applications

- environment for service discovery, advertisement, consumption
- receiving traffic rules from MEPM/apps/services
  and instructing forwarding plane
- receiving DNS records from MEPM and configuring DNS proxy/server
- hosting services, e.g., location, RNI, bandwidth management

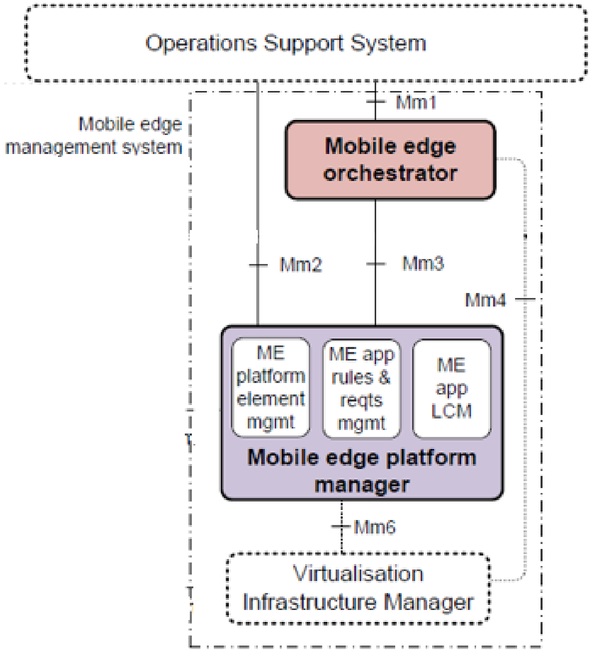
Different ME platforms can communicate via the Mp3 interface



Mobile Edge Platform Manager (MEPM)

The MEPM is responsible for:

- managing application life-cycle
- informing the MEO of application related events
- managing service authorization, traffic rules, DNS configurations
- receiving and processing FM and PM reports from the VIM



Mobile Edge Management System

The heart of the MEMS is the Mobile Edge Orchestrator

The MEO is essentially what we called the AFVO, and it is responsible for:

- maintaining database of resources, hosts, available services
- maintaining topology
- on-boarding new applications
  - authenticity / integrity checking
  - comparing application rules with operator policies
  - instructing the VIM on application specific issues
- selecting ME host for instantiation based on availability and latency
- triggering application based on UE application
- terminating application
- relocating application