Dependable Software Defined In-Network Computing

Elias P. Duarte Jr.

Universidade Federal do Paraná

Curitiba, Brazil

www.inf.ufpr.br/elias

elias@inf.ufpr.br

UFPR

UNIVERSIDADE FEDERAL DO PARANÁ

Agenda

- The Network Softwarization Revolution: Virtualization
- NFV+COIN = NFV-COIN → Synergy!
    - NFV: Network Functions Virtualization
    - COmputing In the Network: COIN
- Other research efforts in dependability:
    - Robustness of software-defined networking
    - FRR (Fast ReRoute) based on Maximum Flow Evaluation
    - Scalable Consensus

Network Virtualization

Virtual Networks A, B and C are on the same physical infrastructure but can run completely different protocol stacks and are mutually isolated from a security point of view
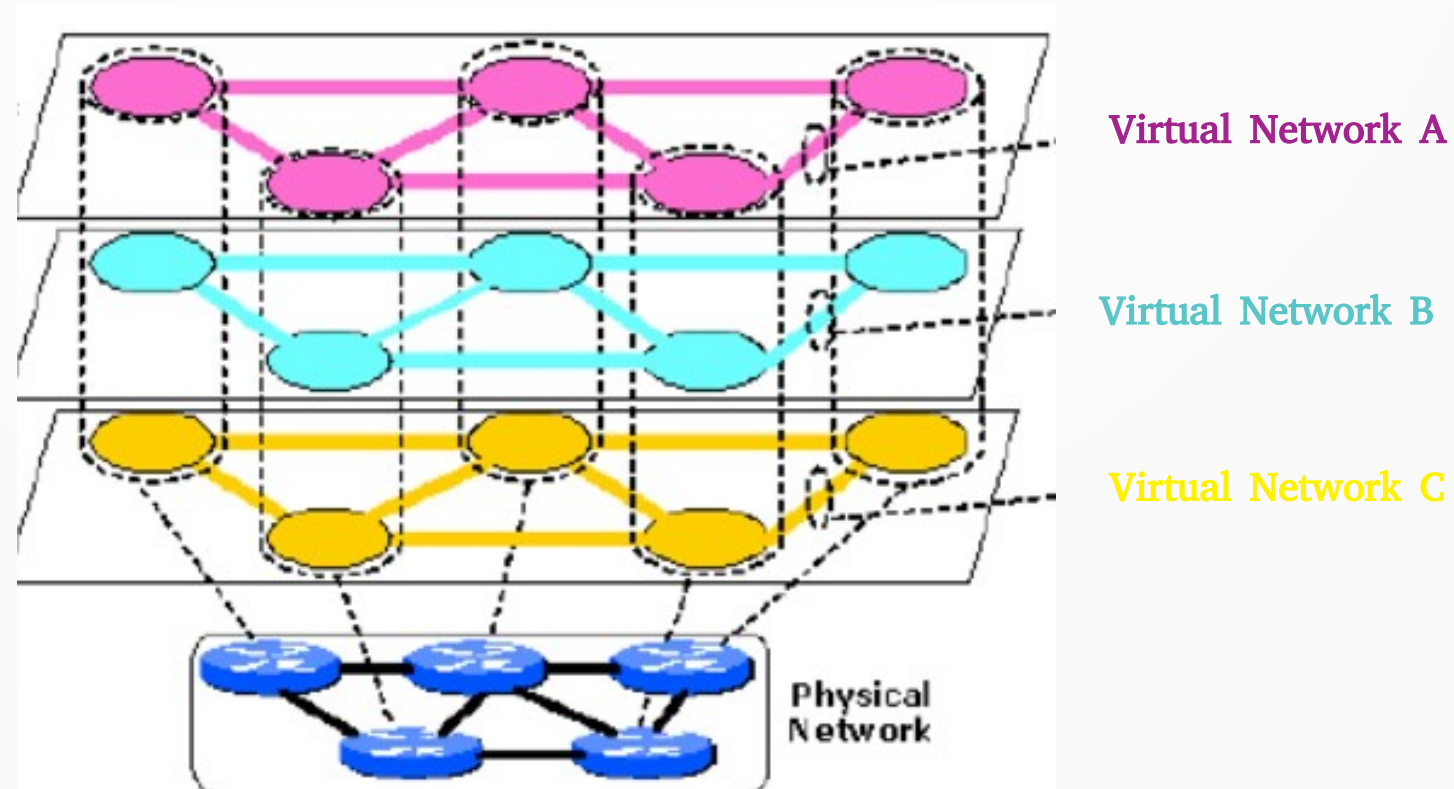
Network Virtualization: Enabling Technologies

1) Software Defined Networking (SDN)

2) Data Plane Programmability

**3) Network Functions Virtualization (NFV)**

NFV: Virtual Network Functions

- NFV was first proposed to allow the implementation of middleboxes in software, using virtualization technology

- Instead of specialized/often proprietary hardware: run virtual functions on off-the-shelf hardware

- Reduces costs: OPEX (OPerational EXpenses) & CAPEX (CApital EXpenses)

- Improves flexibility, management, saves energy, space, …
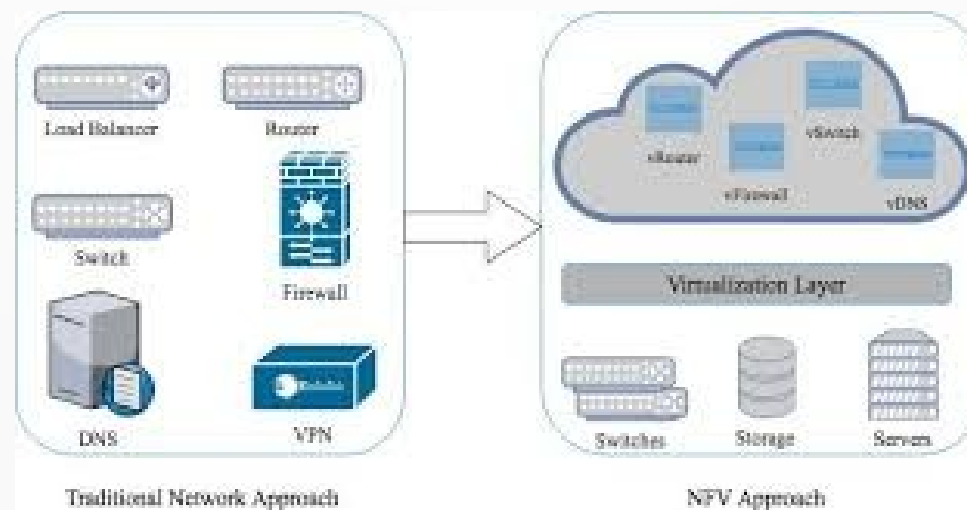
SFC: Service Function Chain

- Besides Individual VNFs (Virtual Network Functions)
- Complex network services can be constructed called <u>Service Function Chains</u> by orchestrating multiple VNFs
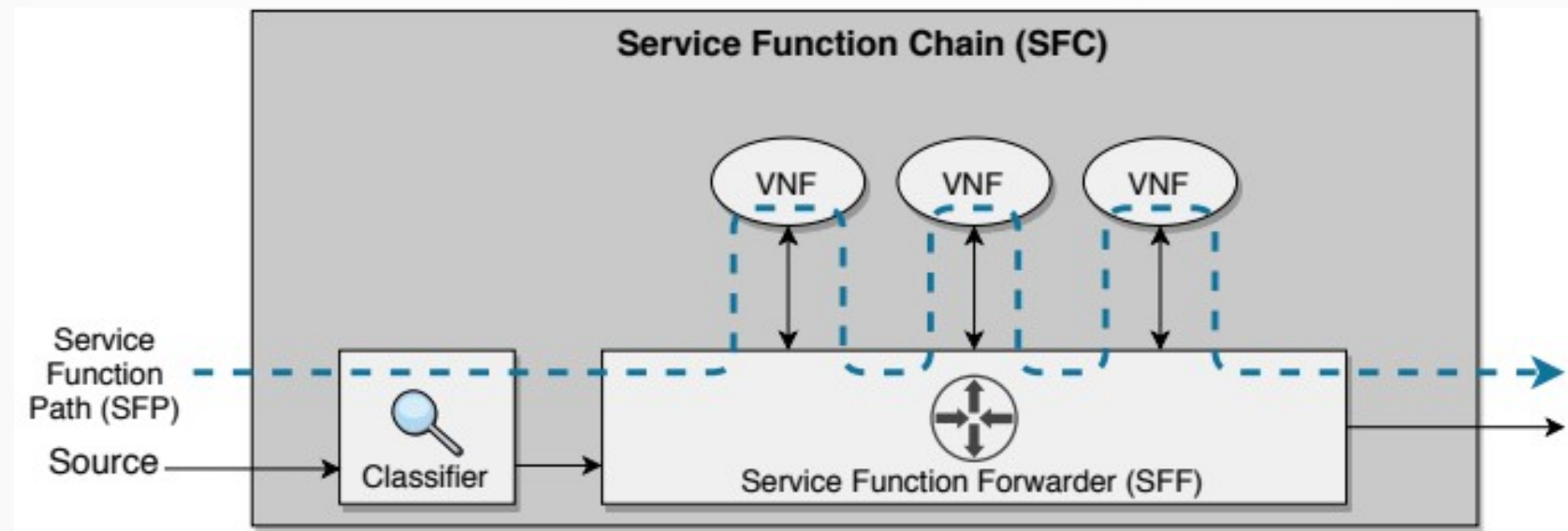
Changing Subjects: INC

- INC is the acronym for <u>In-Network Computing</u>
- COIN: <u>COmputing In the Network</u>
- The idea is to move the application logic into the network
- New services implemented *within* the network
- These services, which are generally executed by hosts on the border…
- … become network services!
- Natively offered by the network itself

synergy

NFV + COIN = NFV-COIN

NFV-*COIN*: **End-User** Point of View

- Think of implementing or running/maintaining an application or middleware yourself, locally...

- ... versus having it readily available from the network, as a native network service

- All the user needs to do is to employ the correct API to *invoke the service that is already there*

NFV-*COIN*: Case Studies

- Flexibility, Flexibility, Flexibility, Flexibility
- Want to use some service? Just invoke it!
- Want to terminate the service? Just stop it!
- Saves energy, space, management is so much easier

Case Studies

- Failure Detector

  - R. Turchetti, Elias P. Duarte Jr., "Implementation of failure detector based on network function virtualization," IEEE/IFIP International Conference on Dependable Systems and Networks Workshops (DSN-W), 2015.

- Consensus

  - G. Venancio, E. Camargo, R. Turchetti, E. P. Duarte Jr., "VNF-Consensus: : A Virtual Network Function for Maintaining a Consistent Distributed SDN Control Plane," International Journal of Network Management, 2020.

- Reliable and Ordered Broadcast

  - G. Venancio, R. Turchetti, E. P. Duarte Jr., "NFV-RBCast: Enabling the Network to Offer Reliable and Ordered Broadcast Services," IEEE/SBC LADC, 2019.

NFV-COIN: Architecture
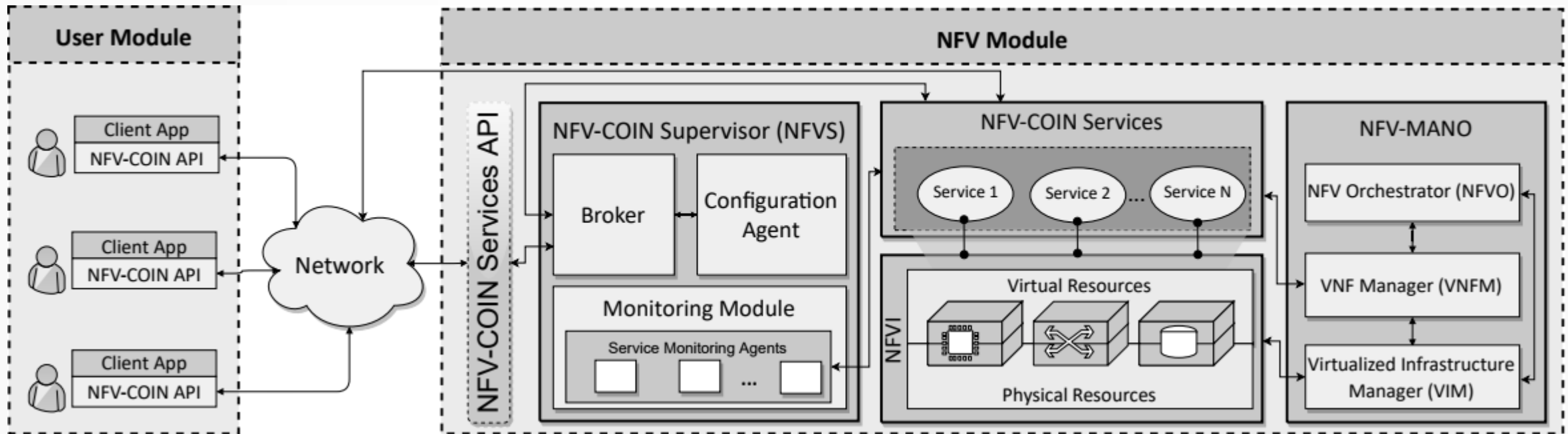
The NFV-COIN IETF Drafts

- Flash news: two NFV-COIN drafts have just been published:
  - an international team with Prof. Younghan Kim, Prof. Jaehoon P. Jeong (South Korea) & al.
- Interface to In-Network Functions (I2INF) - Problem Statement: *draft-jeong-opsawg-i2inf-problem-statement*
- A Framework for the Interface to In-Network Functions (I2INF): *draft-jeong-opsawg-i2inf-problem-statement*
- Already in version 2, hopefully they will become RFCs soon!

The Cloud-Edge-Core Continuum

- We believe INC & COIN fit perfect in the Cloud-Edge Continuum

- Computing is executed along a series a heterogeneous infrastructures

- INC & COIN effectively extend the Continuum to a Cloud-Edge-Core Continuum
  - of course not only the "network core", as computing can run in the Cloud network or Edge network as well

For more info on NFV-COIN:

- G. Venancio, R. Turchetti, E. P. Duarte Jr., "NFV-COIN: Unleashing the Power of In-Network Computing with NFV Technology," *Journal of Internet Services and Applications (JISA)*, Vol. 12, No. 1, pp. 46-53, 2022.

Other Research Efforts on Dependability

# The Robustness of Software Defined Networking

- Typical network middleboxes are used in production networks: five-nines required!

  99.999%

- Replacing of hardware solutions with virtualization
  - multiple software layers
  - new dependability challenges
- Robustness of network software
- Currently: Open VSwitch, in collaboration with Prof. Marco Vieira

Fast ReRoute

- Proactive fault-tolerant routing strategy
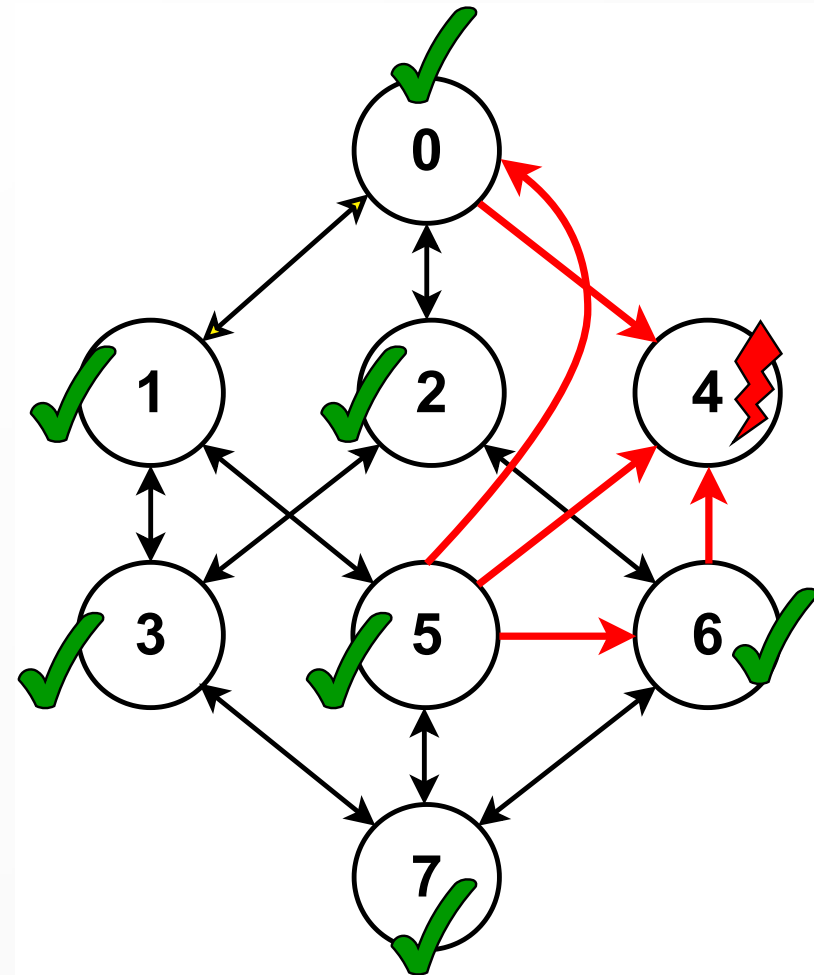- Routes selected *also* with Maximum Flow Evaluation: more alternatives!
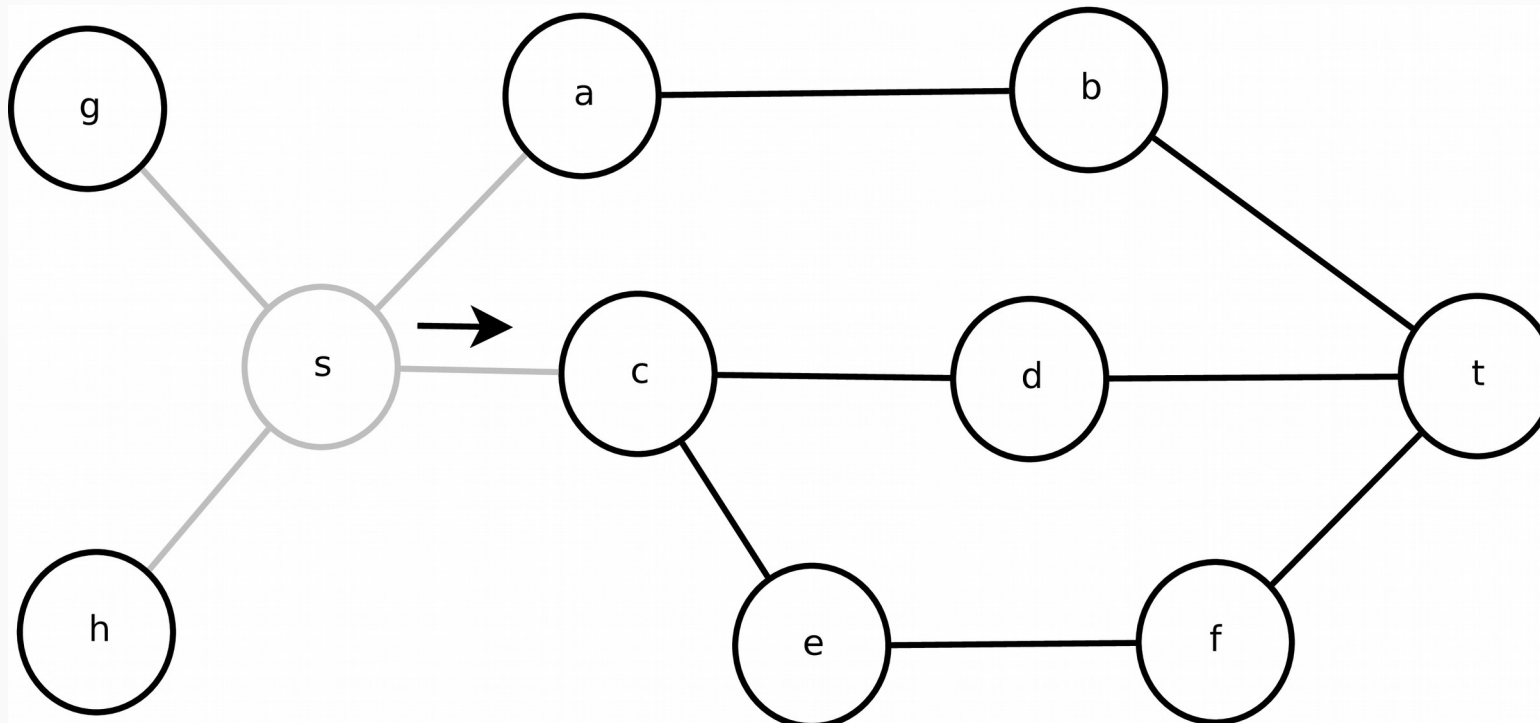
Fast ReRoute with MaxFlow

- For more information:

Leon Okida, M. Schulze-Rosa, Elias P. Duarte Jr., "Fast Reroute with Highly Connected Routes Based on Maximum Flow Evaluation," Corr abs/arXiv:2410.10528, pp. 1-22, 2024.

Scalable Consensus

- The VCube virtual topology
  - organizes processes of a distributed system
  - a hypercube when all processes are fault-free
  - reorganizes itself autonomically as processes fail
  - maintaining several logarithmic properties
- HyperPaxos

Thank you!

elias@inf.ufpr.br
https://www.inf.ufpr.br/elias