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2nd Visions for Future Communications Summit
Technologies and Services Towards 6G

Introducing FlexNGIA: A Fully-Flexible Internet Architecture for the Next-Generation Tactile Internet

Mohamed Faten Zhani

École de technologie supérieure (ÉTS Montreal)

Canada

Lisbon, Portugal, November 28, 2019

Outline

- A Glance into the Future
- Limitations of Today's Internet
- FlexNGIA: Fully-Flexible Next-Generation Internet Architecture
- Use Cases
- Research Challenges

- Keynote at ACM SIGCOMM 2019 Workshop on Networking for Emerging Applications and Technologies (NEAT 2019)
- M. F. Zhani, H. ElBakoury, "*FlexNGIA: A Flexible Internet Architecture for the Next-Generation Tactile Internet,*" ArXiV 1905.07137, May 17, 2019 https://arxiv.org/abs/1905.07137

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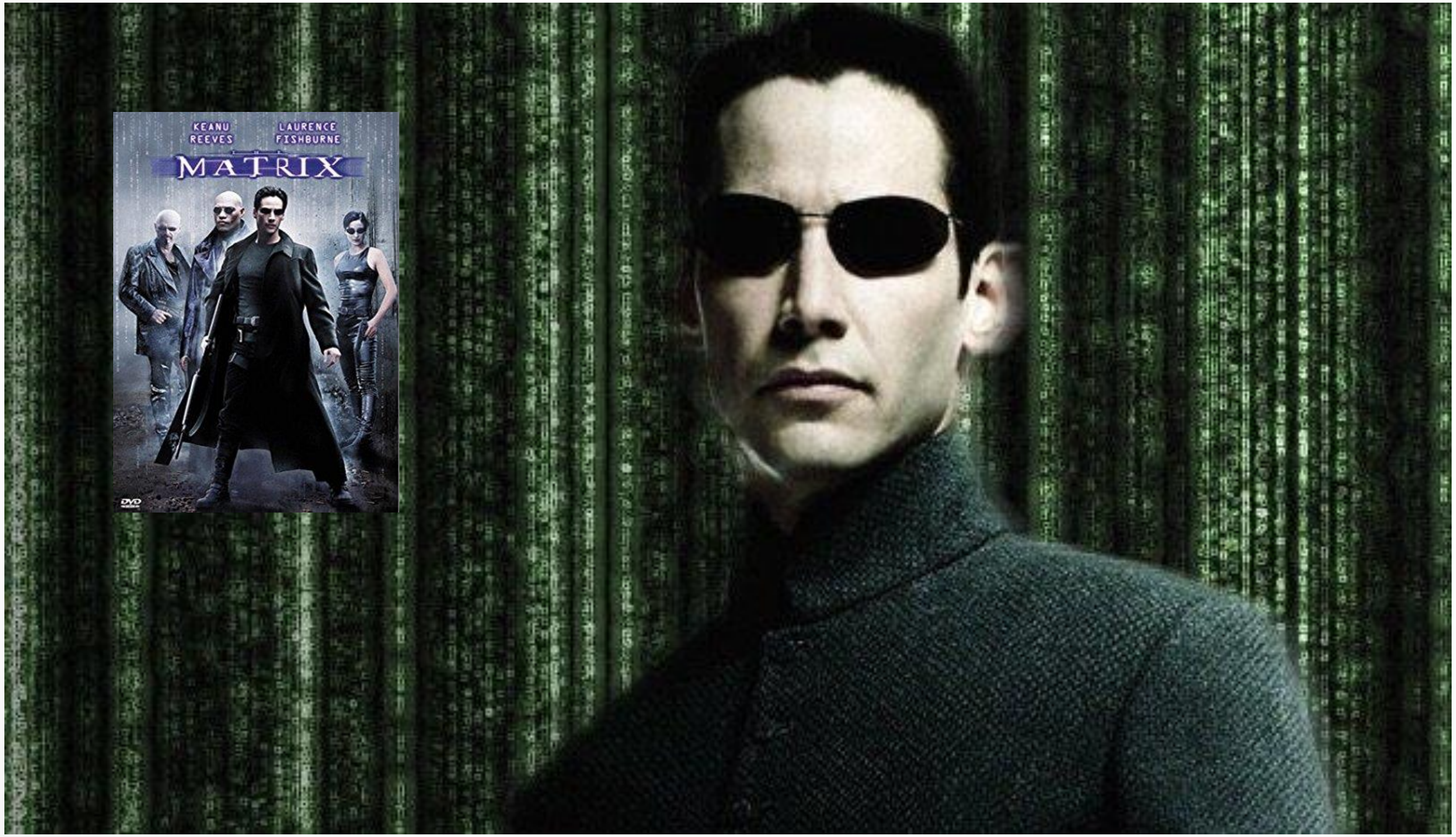
A Glance into the Future

Future Applications

- Telepresence
- Virtual Reality
- Augmented Reality
- Holoportation
- Haptics
- …

Loading…

Welcome to the Matrix



Future Applications Requirements & Characteristics

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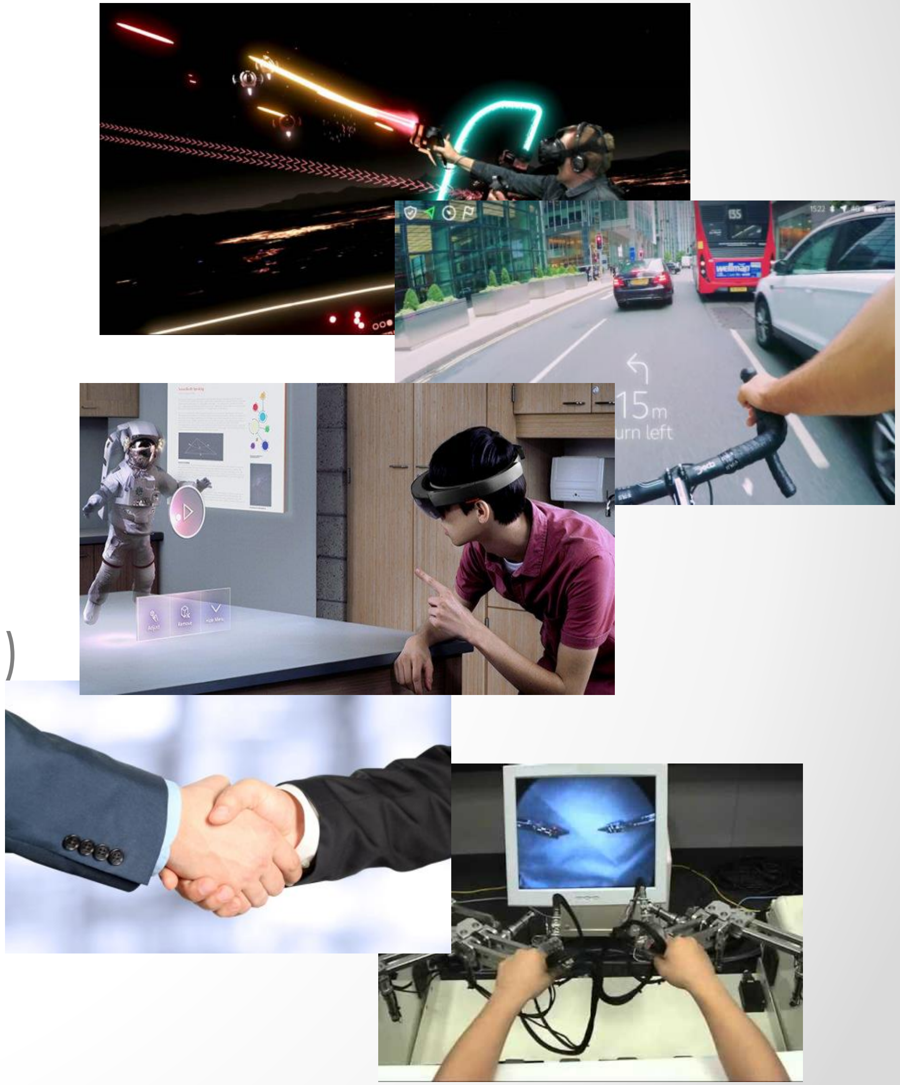
- Characteristics
  - Octopus-like applications: huge number of flows for each application
  - Changing requirements : requirements can change over time
- Requirements:
  - High processing power: real-time processing
  - High bandwidth (e.g., VR (16K, 240 fps) ➔ 31.85 Gbps)
  - Ultra-low Latency: 1ms to 20ms
  - Multi-flow synchronization
  - High availability



M. F. Zhani, H. ElBakoury - FlexNGIA 2019 (https://arxiv.org/abs/1905.07137)

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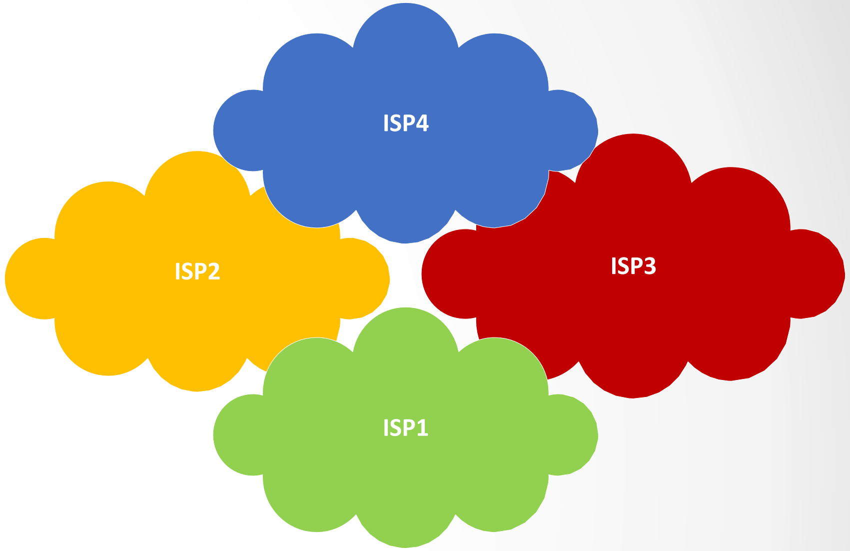
Today's Internet Limitations



- A network of networks
  - No control over E2E performance
  - Offered service: "Best effort"→ data delivery.. no more
- Transport Layer Protocols
  - One-size-fits-all service offering: TCP offers reliability, packet retransmission, congestion and flow control
  - Blind congestion control
  - The two end points limitation
  - Same limitations are inherited by QUIC and SCTP

Today's Internet Limitations (2)

- Network layer protocols and services
  - Not aware of the applications characteristics and requirements (which flow belongs to which app?, priorities?)
  - No collaboration with upper layers (transport, application)
    - The network knows better about the congestion (e.g., location, severity)
    - The network could help with reliability (e.g., retransmission)…
- Packet header
  - Not easy to include metadata or commands
  - Whose is going to use such metadata/commands?

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FlexNGIA

FlexNGIA

Computing resources

- In-Network Computing: any function anywhere

Business model

- Network providers offer Service Function Chains/meshes
- Stringent performance requirements

Cross-layer Design (Transport+Network)

- Breaking the end-to-end paradigm
- In-network advanced transport functions
- Better congestion control
- Stringent performance and reliability guarantees

Application-Aware Network Services

- Advanced functions tailored to applications
- App-aware traffic engineering

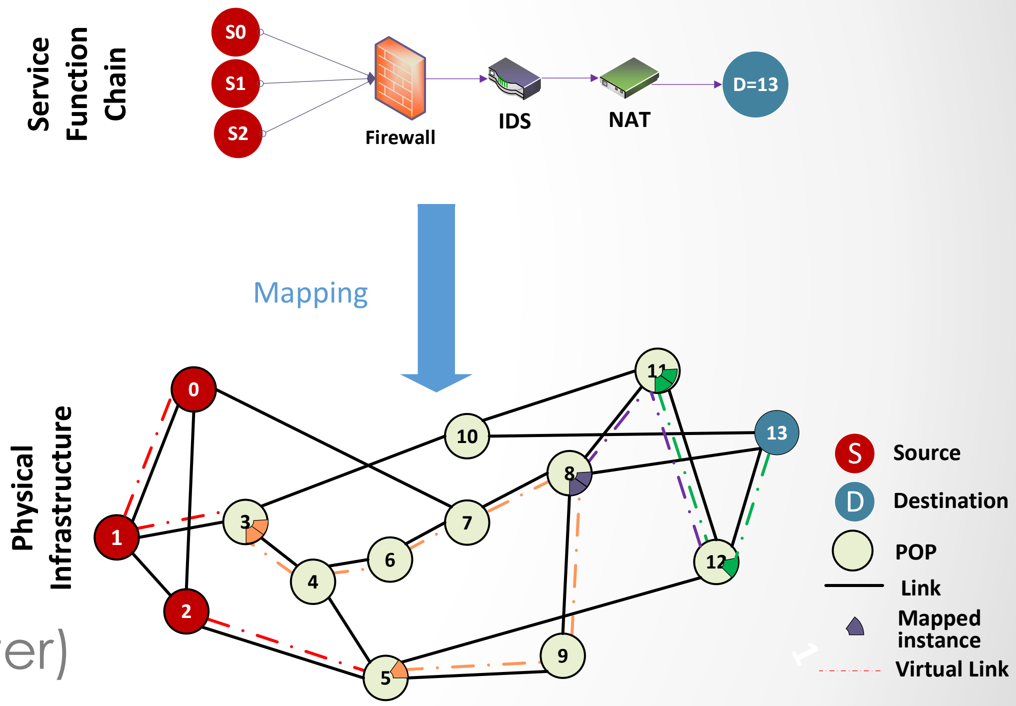
Flexible headers

- Tailored to the application

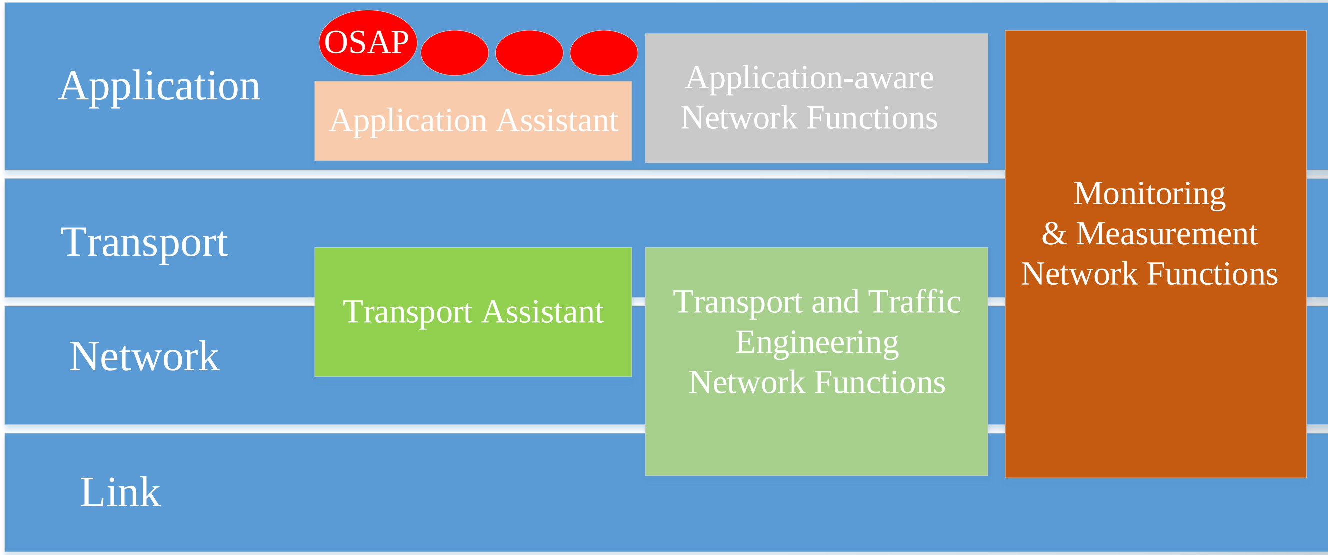
Future Internet Services

Service Function Chain/Mesh (SFC):

- Multiple sources and destinations
- Define your Network Functions: type, software, behavior, input/output packet format, expected processing delay, buffer size
- Define communication protocols (layer 3 and above)
- Define performance requirements (e.g., throughput, packet loss, end-to-end delay, jitter)



Network Protocol Stack/Functions



- Basic Network Functions (e.g., packet forwarding)
- Advanced Network Functions:
  - Could operate at any layer
  - Only limited by our imagination
  - Examples: packet grouping, caching and retransmission, data processing (e.g., image/video cropping, compression, rendering, ML), application-aware flow multiplexing (e.g., incorporating/merging data)

➔ Functions could break the end-to-end principle

➔ SDN++: SDN should go beyond configuring forwarding rules and should provide the ability to dynamically configure these new functions

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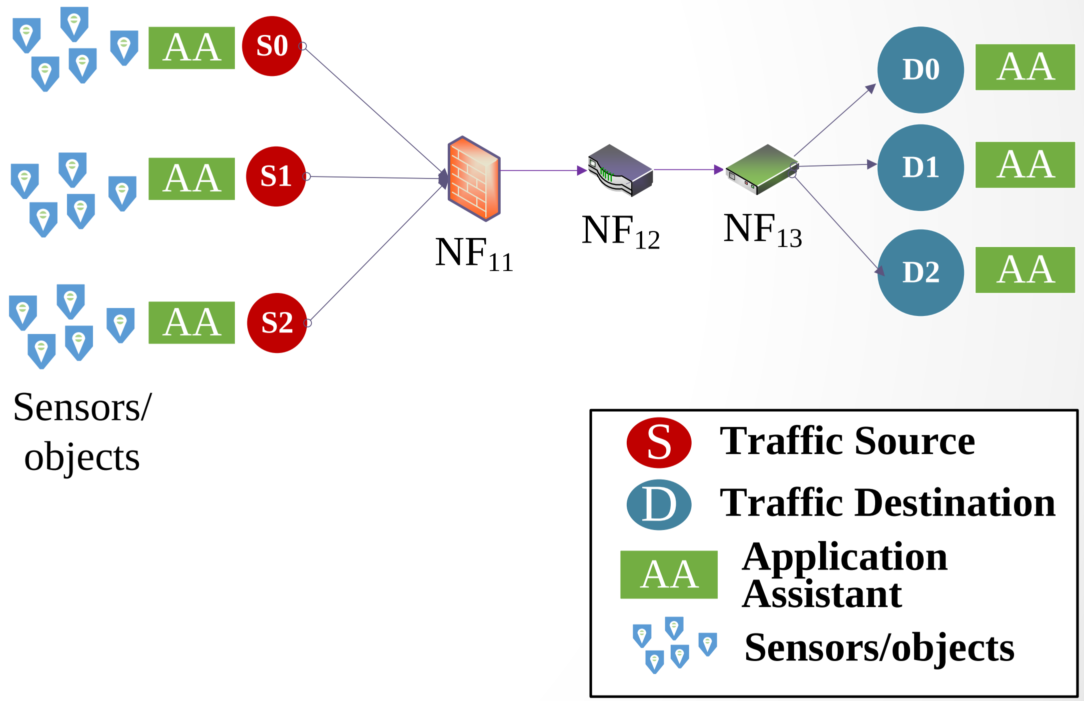
Application Assistant (AA)

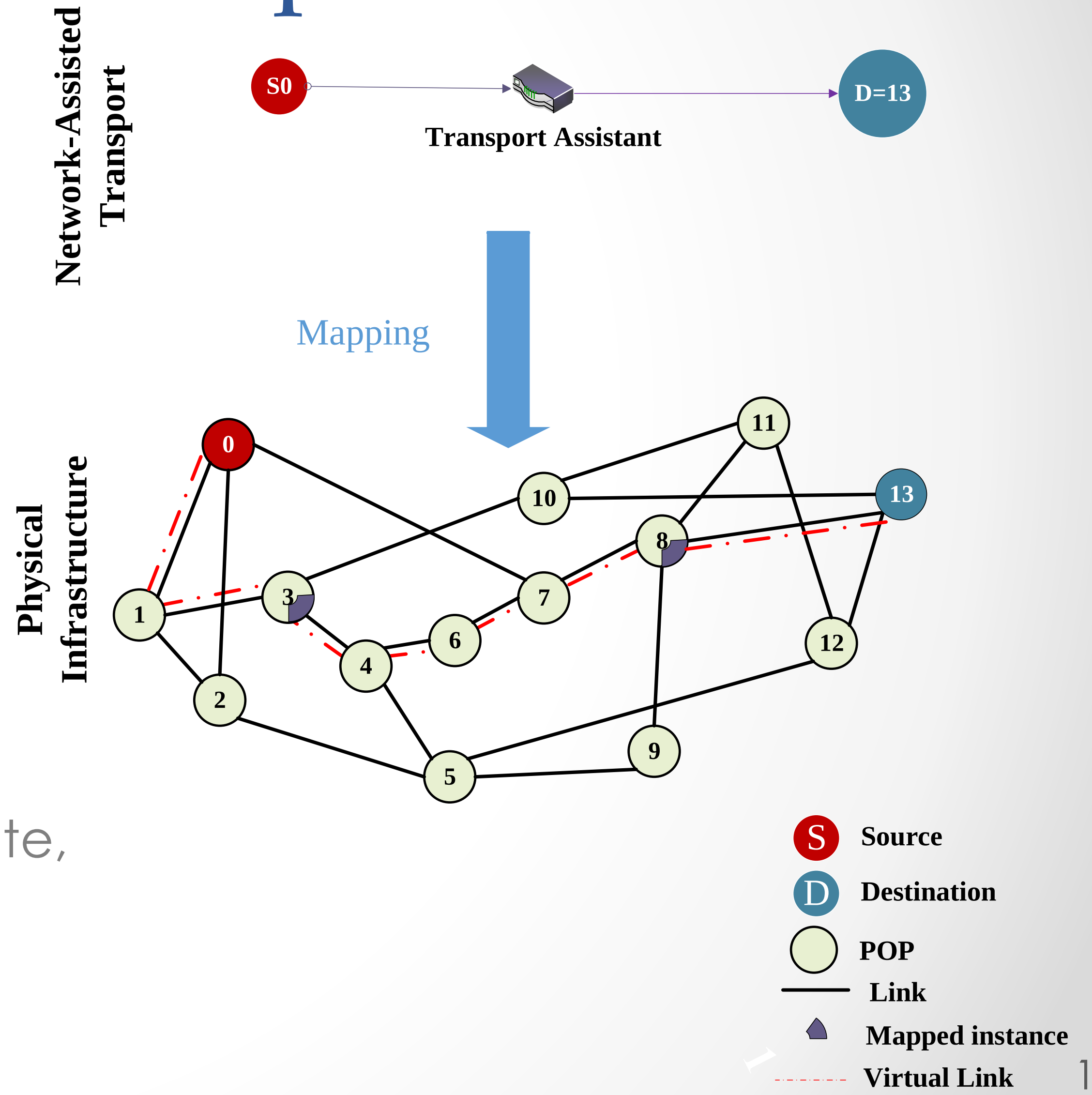
- One AA at each end-point
- Interfaces with objects/sensors
- Measures the application performance and user QoE
- Identifies the applications' requirements at run-time
- Adds additional metadata to be used by subsequent Network Functions

➔ Application-Aware Network Services



Network-Assisted Reliable Data Transport

- Goal
  - Minimize retransmission delay
  - Improved congestion control
- Solution: service chain with a "transport Assistant" function
- Services of the Transport Assistant:
  - Combines transport and network layers
  - Cache and retransmit packets
  - Detect packet loss
  - Routing and congestion control: adjusting rate, dropping packets



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Mixed Virtual Reality and Holograms

- Users are exploring a virtual reality environment with several human holograms and objects
- Challenges
  - How many intermediate functions?
  - What kind of functions?
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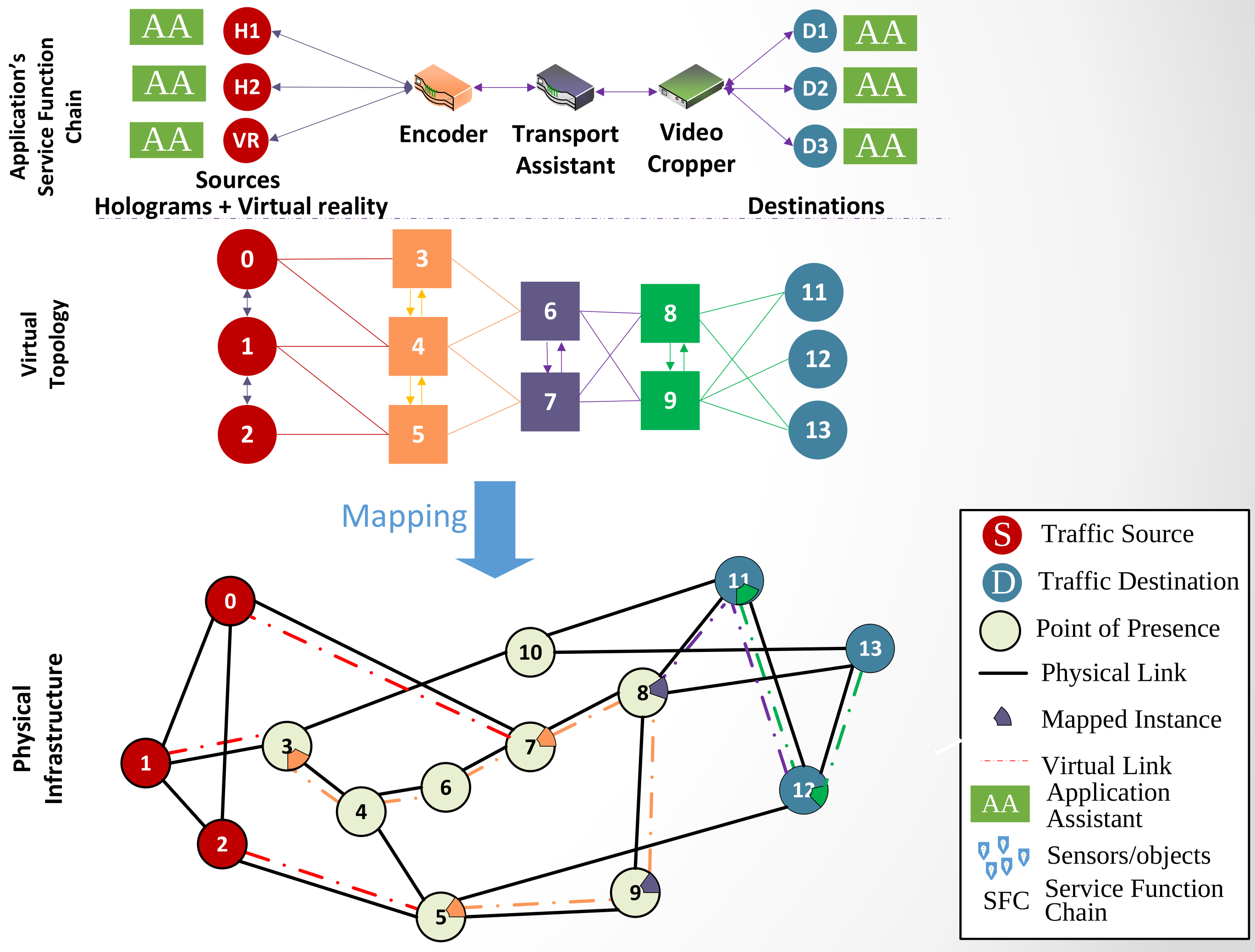

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Research Challenges

- Designing Service Function Meshes tailored to applications
- High-performance softwarized functions
- Signaling
- Slicing/Resource Allocation
- Fault-tolerance and Failure Management
- High-precision and fine-grained monitoring and measurements
- SDN++
- Distributed cross-layer transport protocol (socket, caching, communication)
- Security and Privacy

Looking for More Details?

- Mohamed Faten Zhani, https://profs.etsmtl.ca/mfzhani/
- FlexNGIA Project: M. F. Zhani, H. ElBakoury, "*FlexNGIA: A Flexible Internet Architecture for the Next-Generation Tactile Internet*," ArXiV 1905.07137, May 17, 2019 https://arxiv.org/abs/1905.07137
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Questions

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ACM SIGCOMM 2019 Workshop on Networking for Emerging Applications and Technologies (NEAT 2019)

FlexNGIA
A Fully Flexible Novel Architecture for the Next-Generation Tactile Internet

Mohamed Faten Zhani

École de technologie supérieure (ÉTS Montreal)

University of Quebec

Canada

Beijing, China, 19 August 2019

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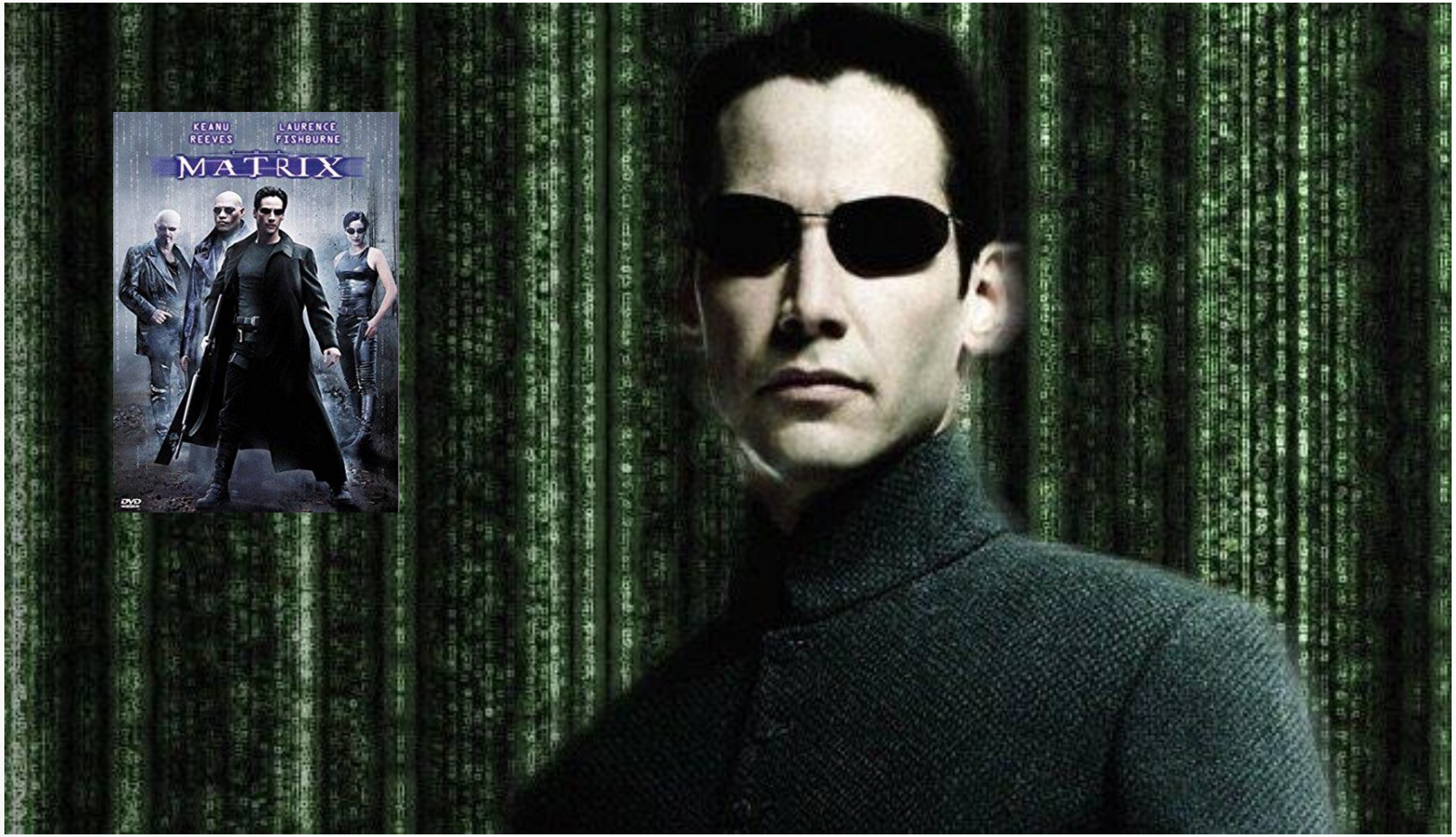

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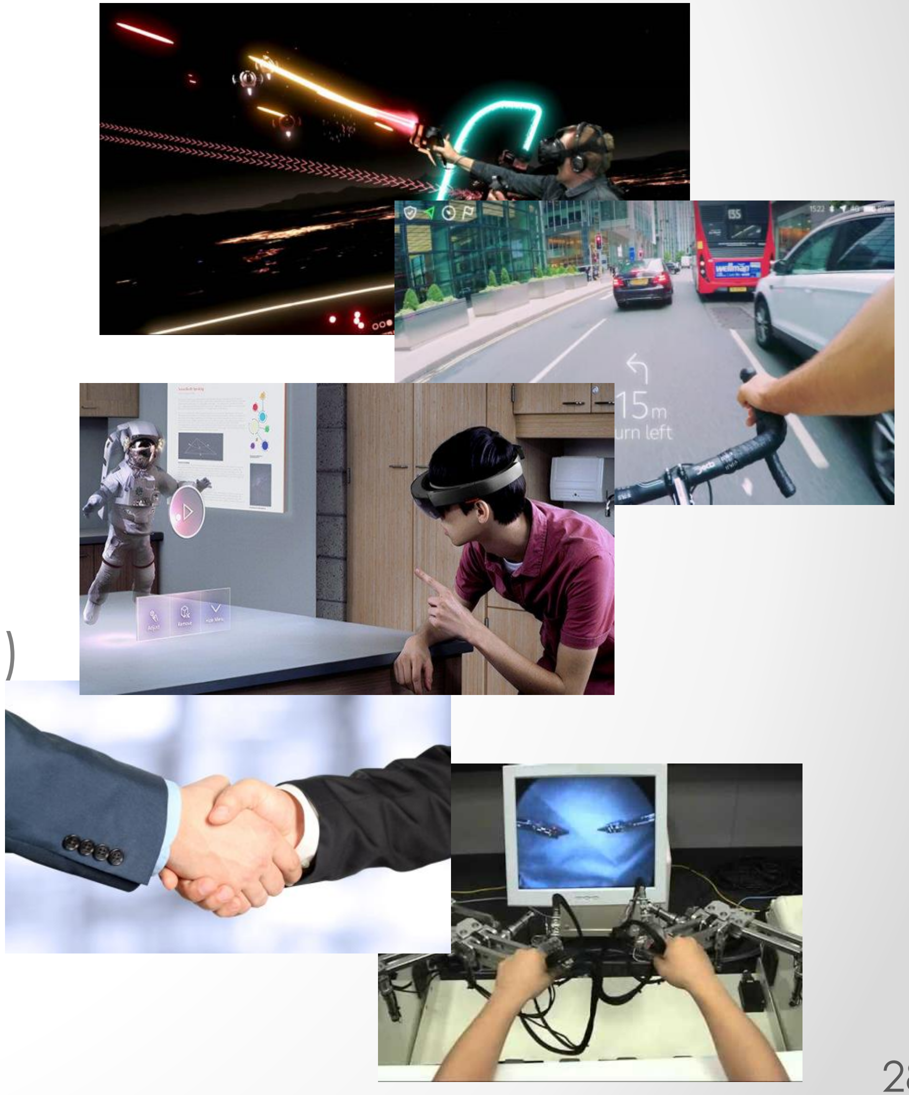


Outline

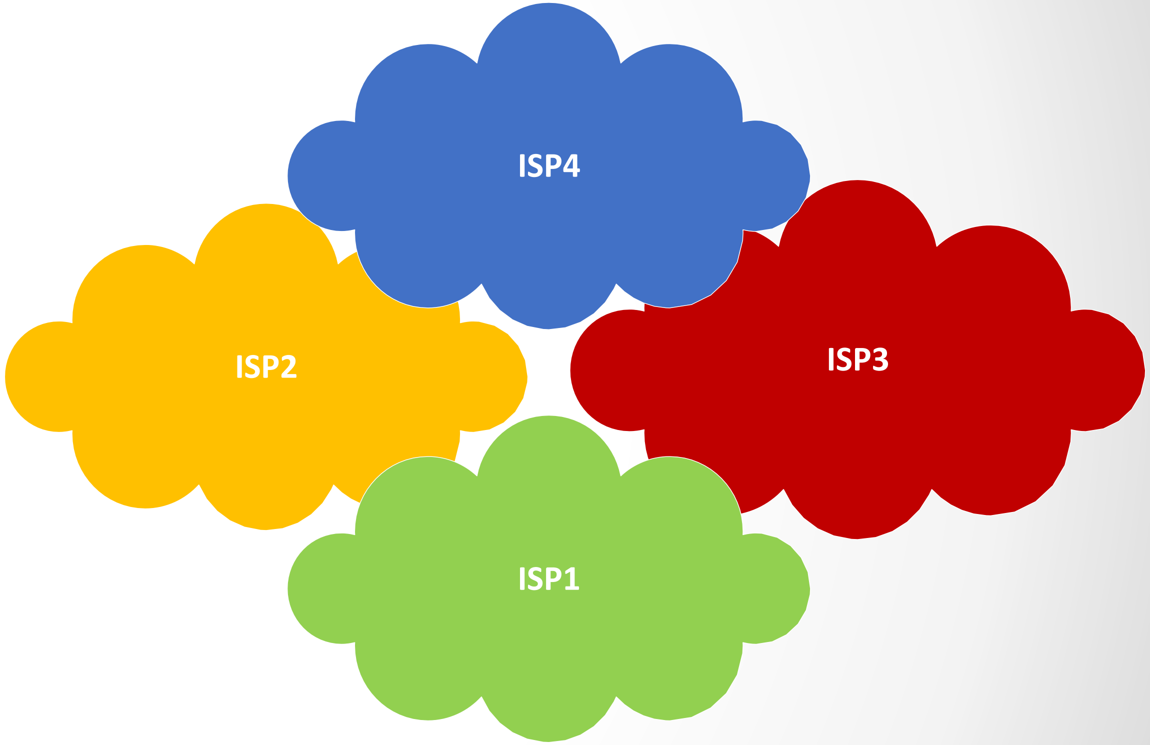
- A Glance into the Future
- Limitations of Today's Internet
  - Internet Infrastructure and Services
  - Network Stack Layers and Headers
- FlexNGIA: Fully-Flexible Next-Generation Internet Architecture
- Use cases
- Conclusion

Internet Infrastructure and Services

- A network of networks
- Offered service: "Best effort" data delivery.. no more
- No control over the infrastructure

  ➔No control over the end-to-end path and quality of service

  ➔No performance guarantees



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Transport Layer Protocols

Many modern protocols like SCTP and QUIC but let's focus first on TCP..

- One-size-fits-all service offering: TCP offers reliability, data retransmission, congestion and flow control
- Blind Congestion control
- The two end points limitation:
  - High retransmission delays (~ 3x e2e delay)
  - Transport and network layers are not aware which flows belong to the same application

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Network Layer Protocols

- Not aware of the applications
  - The application composition (in terms of flows)
  - Performance requirements of each of these flows and how these requirement change over time

  ➔Drop packets « blindly »
- No collaboration with the transport layer
  - Do not provide explicit feedback or support to transport layer (maybe ECN is interesting but it is not enough)
  - Do not help with other transport services (e.g., reliability)

Network Stack header

Problems with current headers:

- Do not provide additional informations about objects/sensors, flows belonging to the same application, applications' requirements, etc.
- Not flexible enough: It is not easy to incorporate meta-data and commands

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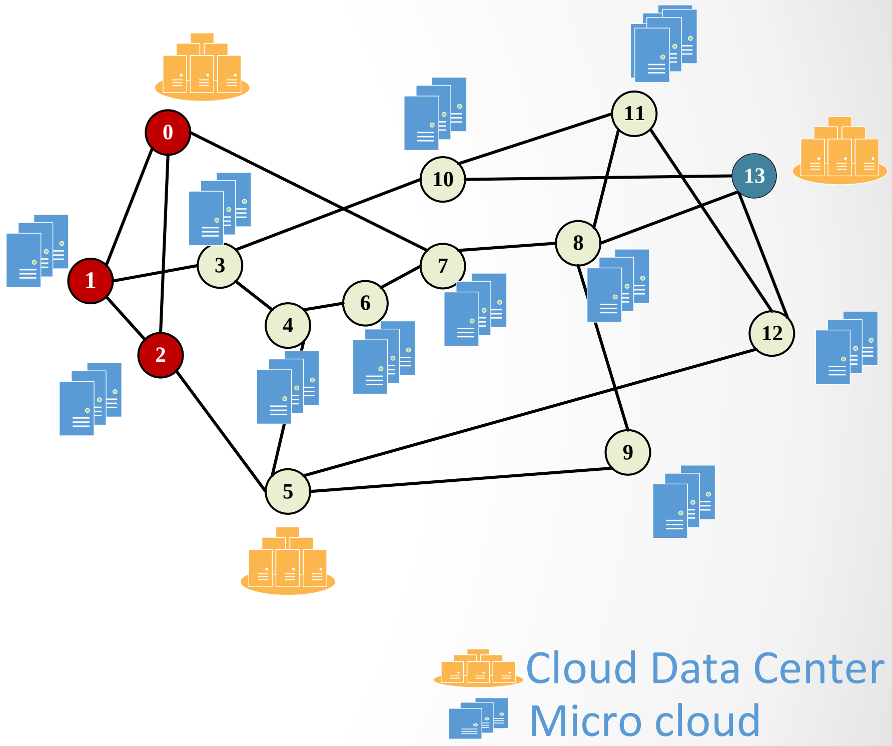
Outline

- A Glance into the Future
- Limitations of Today's Internet
- FlexNGIA: Fully-Flexible Next-Generation Internet Architecture
    - Future Internet Infrastructure and services
    - Business Model
    - Management Framework
    - Network Protocol Stack/Functions
    - Stack Headers
- Use cases
- Conclusion

Future Internet Infrastructure and Services

How a network will look like?

- Computing resources are everywhere: Available at the edge and at the core of the network
- Commodity servers but also dedicated hardware, FPGA, GPU, NPU, etc.
  - ➔ In-Network computing
  - ➔ Reduce steering delay
  - ➔ Full Programmability: Any function could be provisioned anywhere (virtual machines/containers)



Future Internet Infrastructure and Services

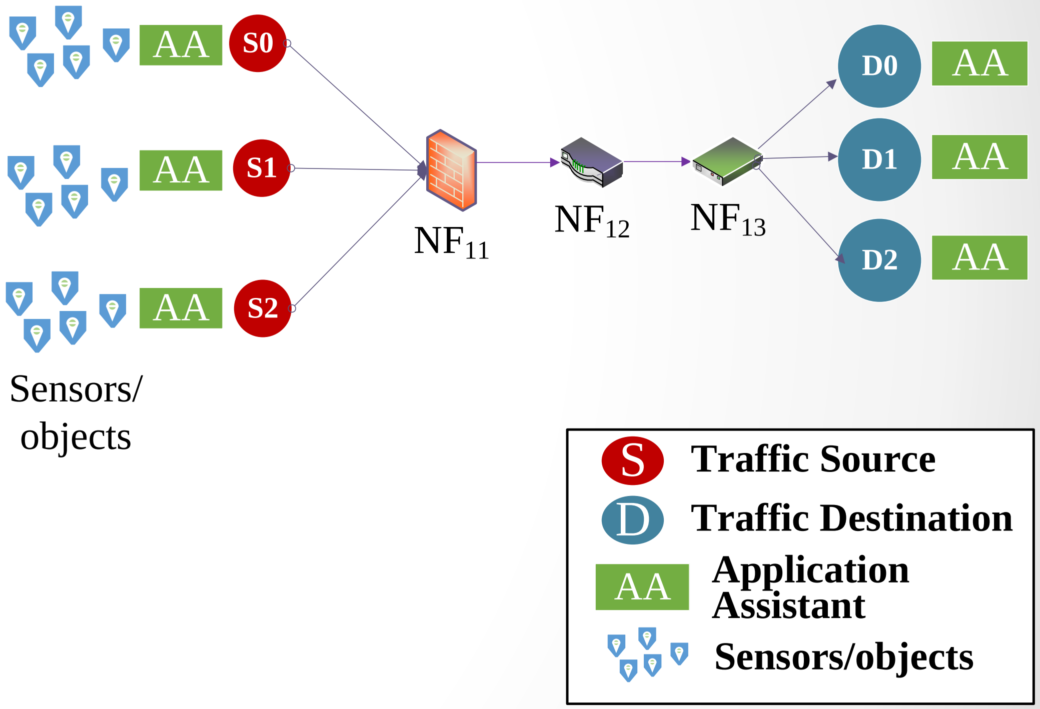
How does Future Internet look like?

- Still a network of networks..
- What is new?
  - More services: Service Function chains
    ➔More advanced functions
    ➔More than just delivery
  - Stringent performance guarantees

Future Internet Infrastructure and Services

Service Function Chain (SFC)

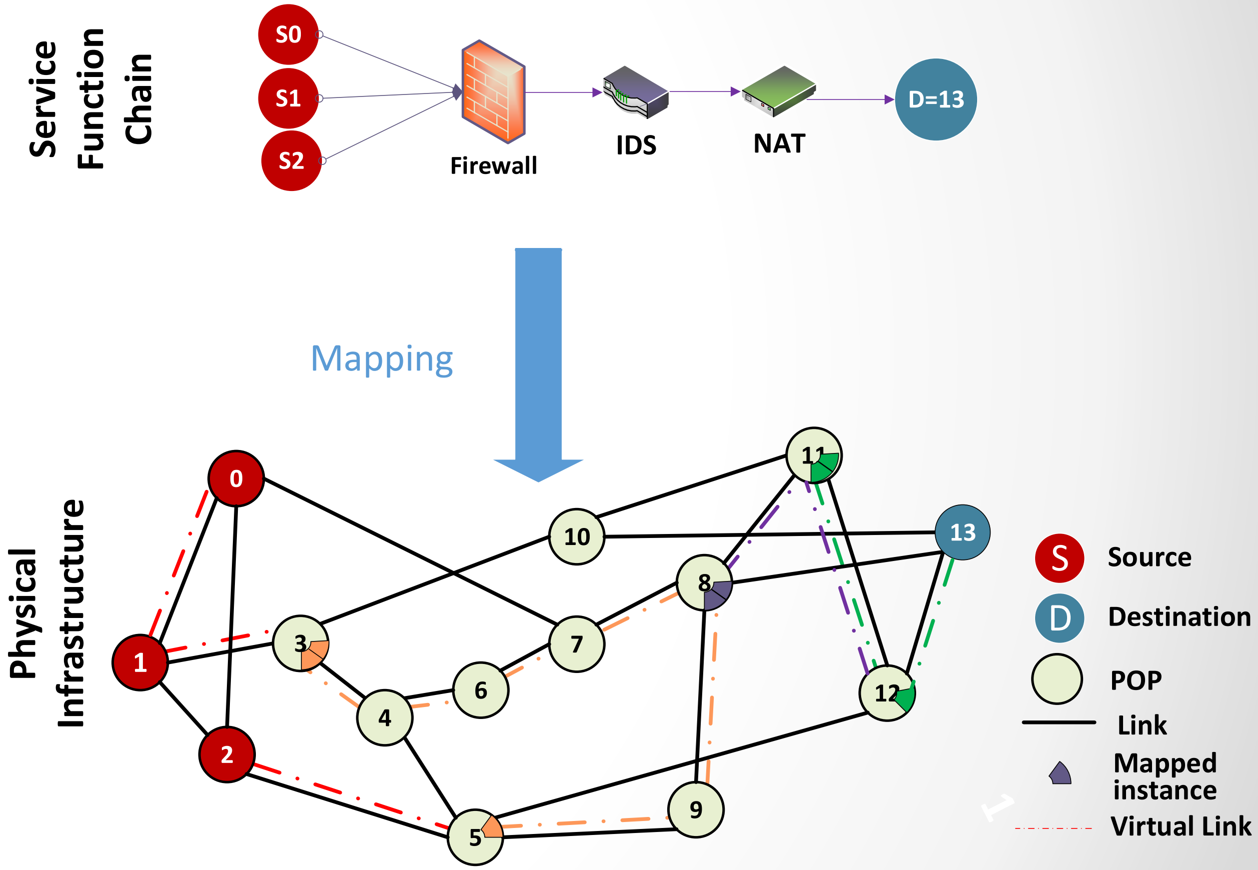
- Multiple connected network functions
- Multiple sources and destinations
- Made out from Network Functions
- Defines, for each network function, the type, software, input/output packet format, expected processing delay, buffer size
- Defines performance requirements (e.g., throughput, packet loss, end-to-end delay, jitter)



Business Model

Network Operators

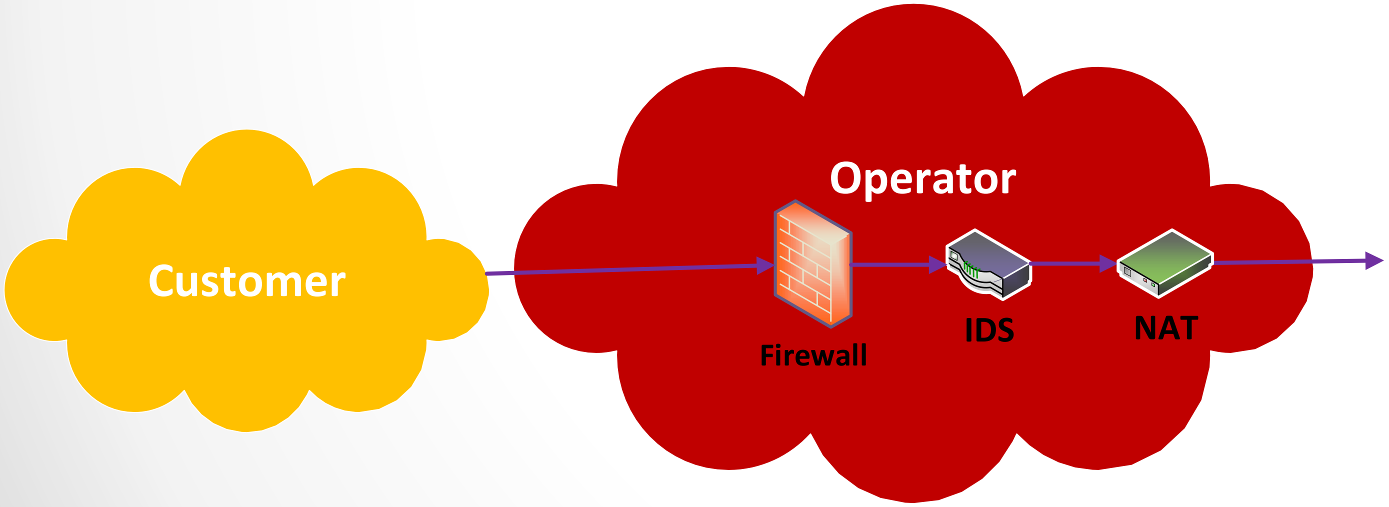
- Own and manage the physical infrastructure (i.e., one network)
- Deploy platforms and software required to run network functions
- The service could be simply data delivery or a SFC
- Provision and manage SFCs



Business Model (cont)

Customers

- Could be other network operators, companies or Institutions
- Define the required SFC and Identify the chain sources/destinations
- Rely on the operator to provision and manage the SFC and satisfy SLA

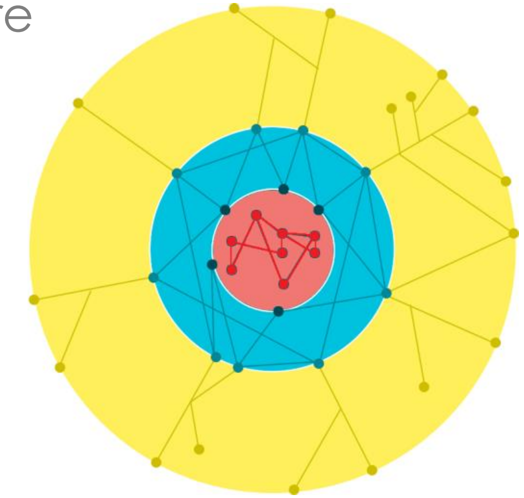


- SFC composition
- SLA requirements for the SFC
  - Bandwidth
  - End-to-end delay
  - Reliability, availability
- SLA requirements for each NFs
  - Processing power
  - Packet format(s)
  - Packet drop criteria…

M. F. Zhani, H. ElBakoury - FlexNGIA 2019 (https://arxiv.org/abs/1905.07137)

Business Model (cont)

- Example of potential Network Operators:
  - ISPs (e.g., AT&T or Bell Canada) and web-scale companies (e.g., Google, Facebook, Amazon)
  - Example: Google Cloud Platform
    - World wide global Infrastructure
    - Software defined platform
    - Full control over the infrastructure



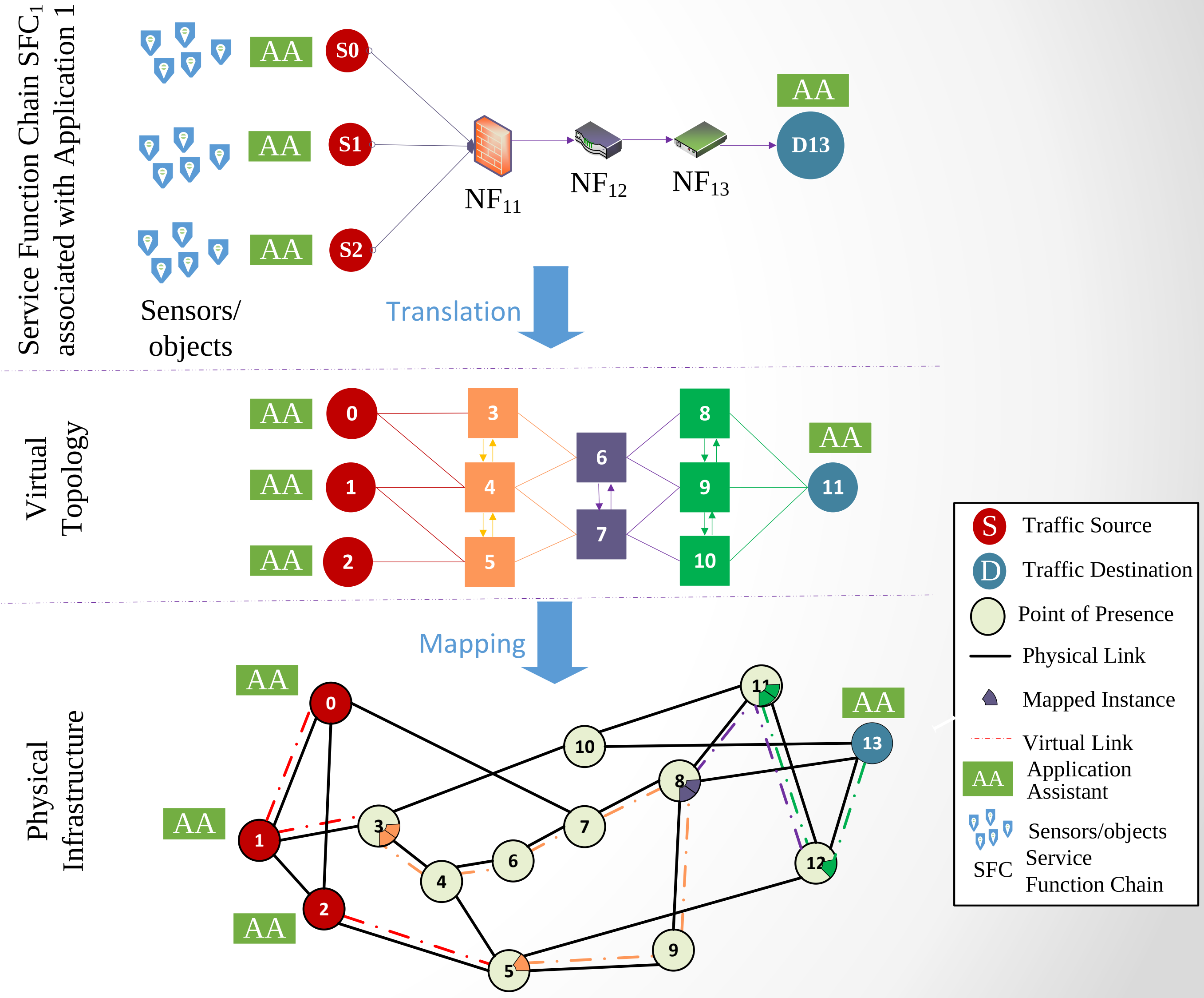
15 Data centers
100 Points of Presence (PoPs)
1000+ Edge nodes

Source: cloud.google.com

Resource Management Framework

Resource Allocation

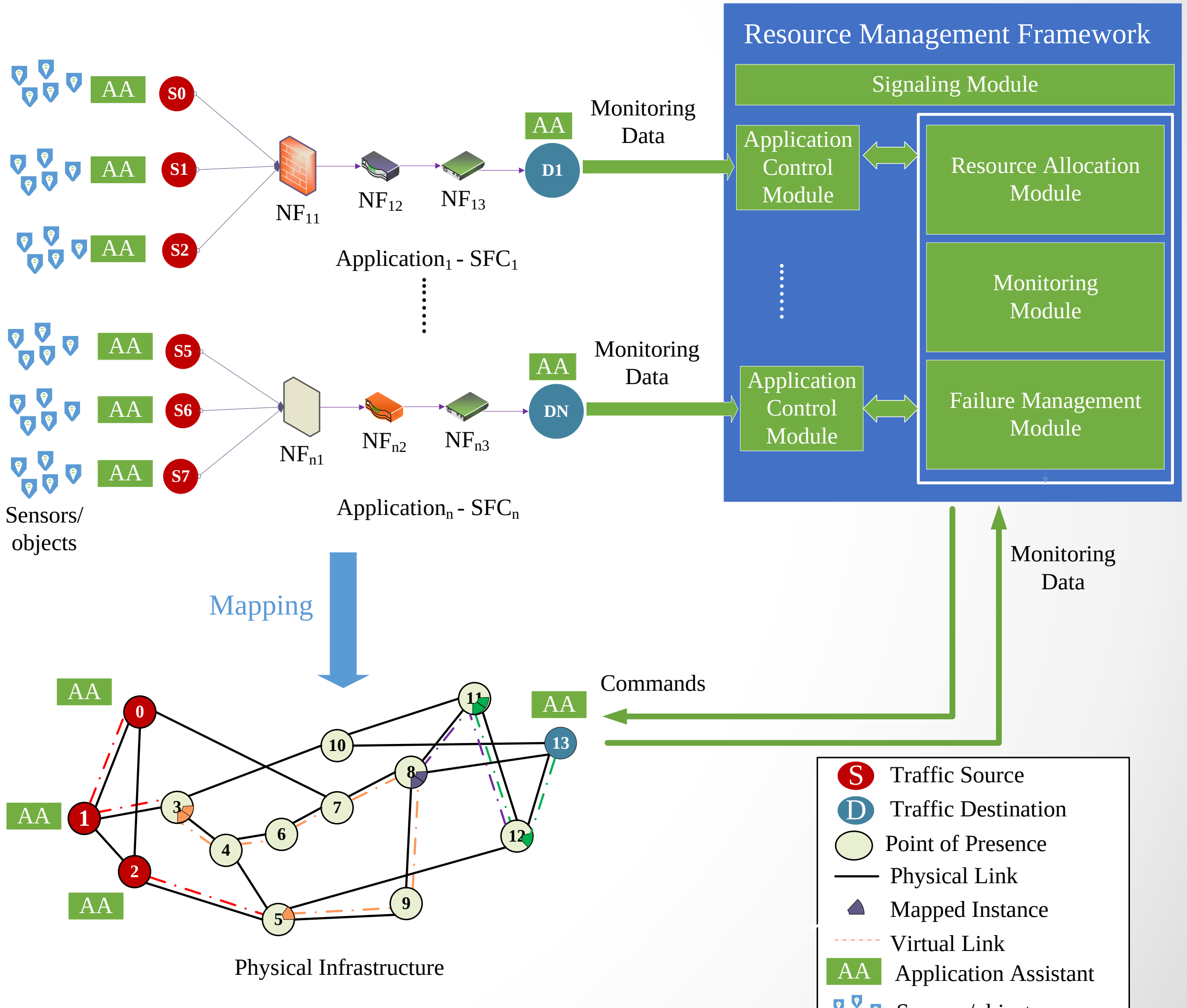
- The Service Function Chain (SFC) is defined by the application designer
- 2-step resource allocation:
  - Translation: the SFC is translated into a virtual topology
  - Mapping: virtual topology are mappa



Resource Management Framework

Main components:

- Signaling module
- Application Control Module
- Ressource allocation Module



NB: For simplicity, the figure shows only the mapping of the chain SFC_1 associated to Application 1

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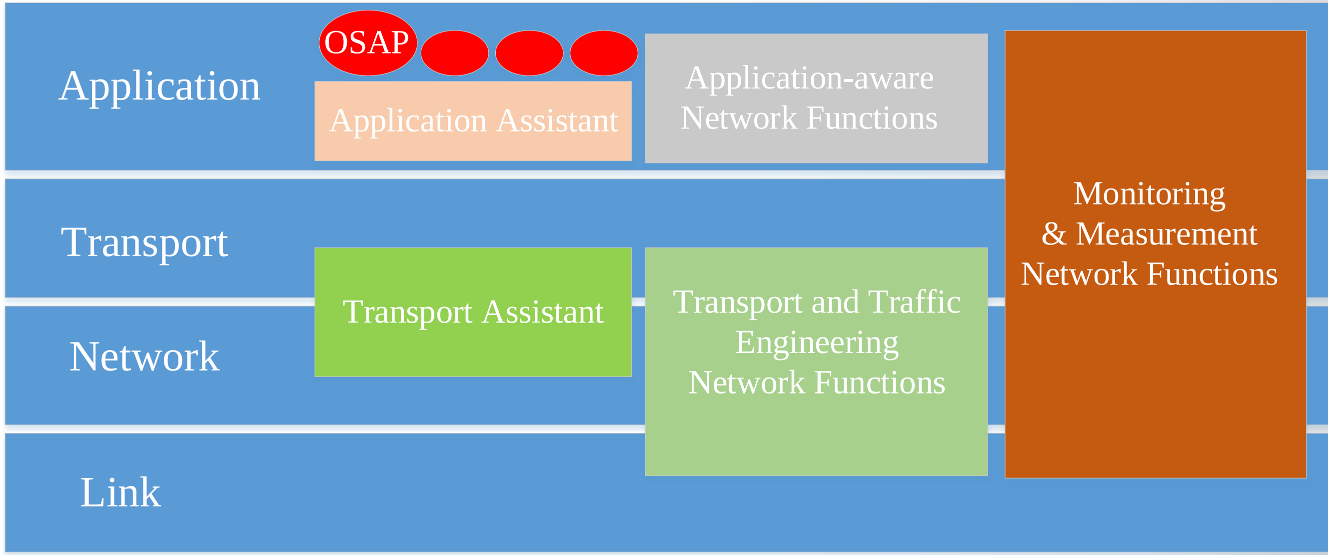
Network Protocol Stack/Functions



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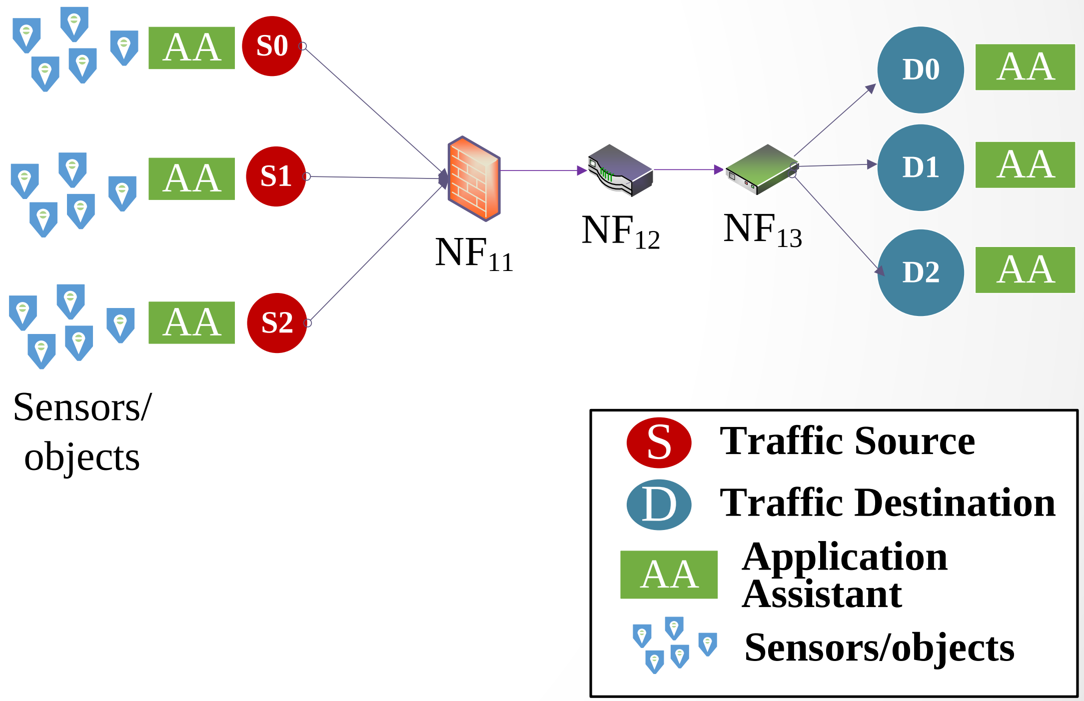

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Network Protocol Stack/Functions Transport Assistant

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Transport Assistant (TA)

- A cross-layer Network Function
- Combines services of the transport and network layers
- Manages all the flows of the same application
- Implements Transport/Network functions (e.g., congestion control, packet loss detection, packet cache and retransmission, routing)
- One or multiple TA could be provisioned in the same SFC

Application Layer

Transport Layer (TCP)
- E2E communication
- Blind congestion Control
- Inaccurate Packet Loss Detection
- Guaranteed Reliability
- E2E Packet Retransmission Process

Network Layer
- IP protocol (header and addressing)
- Routing Protocols/SDN
- ICMP for Control Information
- No Advanced Network Functions

Cross-Layer Transport
- Multi-point communication
- Network-assisted congestion control
- Network-assisted reliability and performance guarantees
- Accurate packet loss detection
- Variable performance and reliability Requirements over time
- Variable Header
- Meta-data and commands within packet headers
- Advanced Network Functions

Link Layer

Network Stack Headers

- Signaling packets
  - Instantiate an application
  - Convey application requirements
- Data packets: carry data
  - Layer 2 header: contains mainly the application id used for packet forwarding (similar to VLANs)
  - Upper layers:
    - Fully flexible header format (customizable meta-data and commands)
    - Defined depending on the application
    - Network functions should be aware of the expected format

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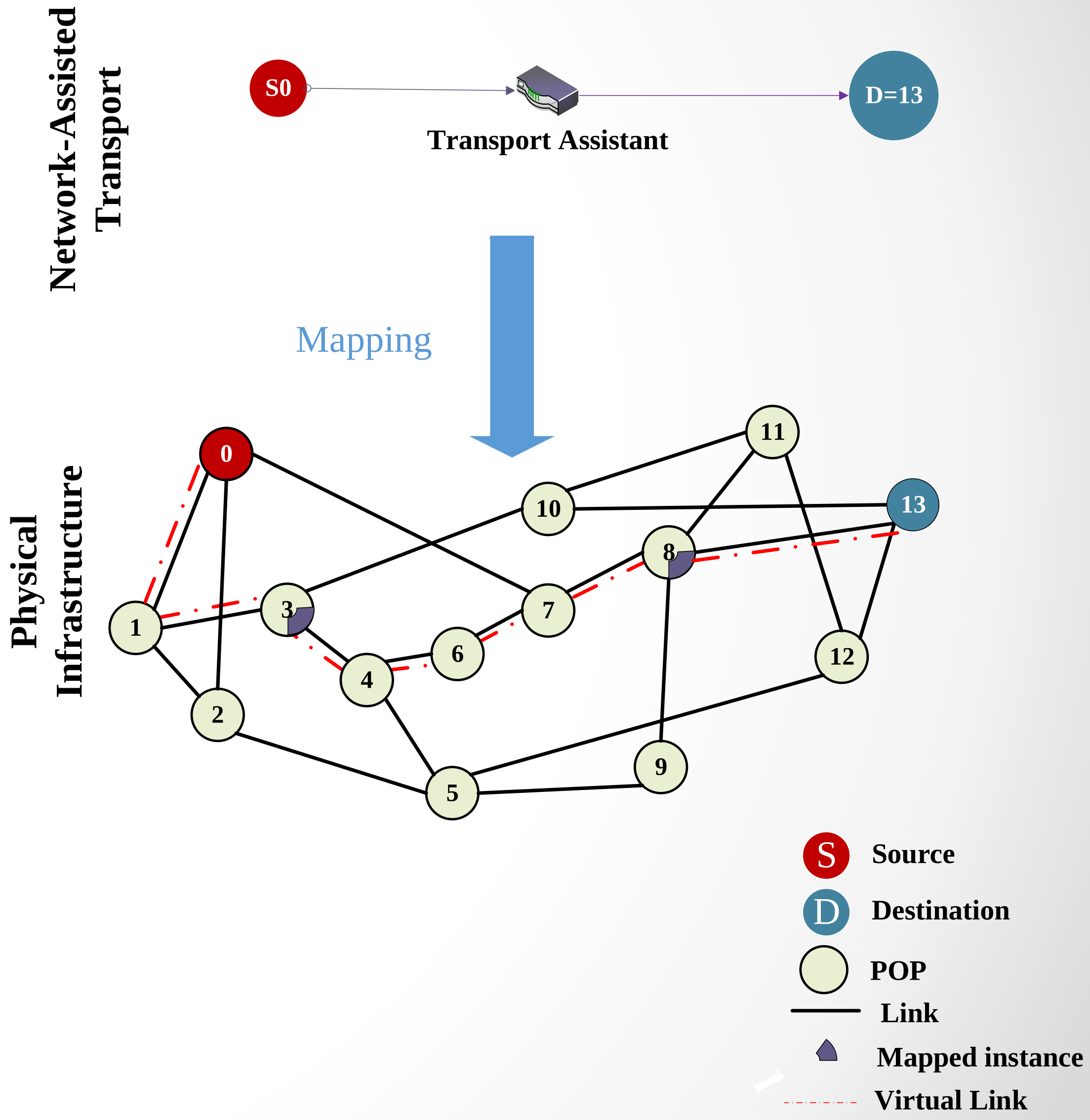
Network-Assisted Data Transport

- Goal
  - Minimize retransmission delay
  - Improved congestion control
- Solution: service chain with a "transport Assistant" function
- Service of the Transport Assistant:
  - Caching and retransmissting packets
  - Detecting packet loss
  - Congestion control: adjusting rate, dropping packets, compression



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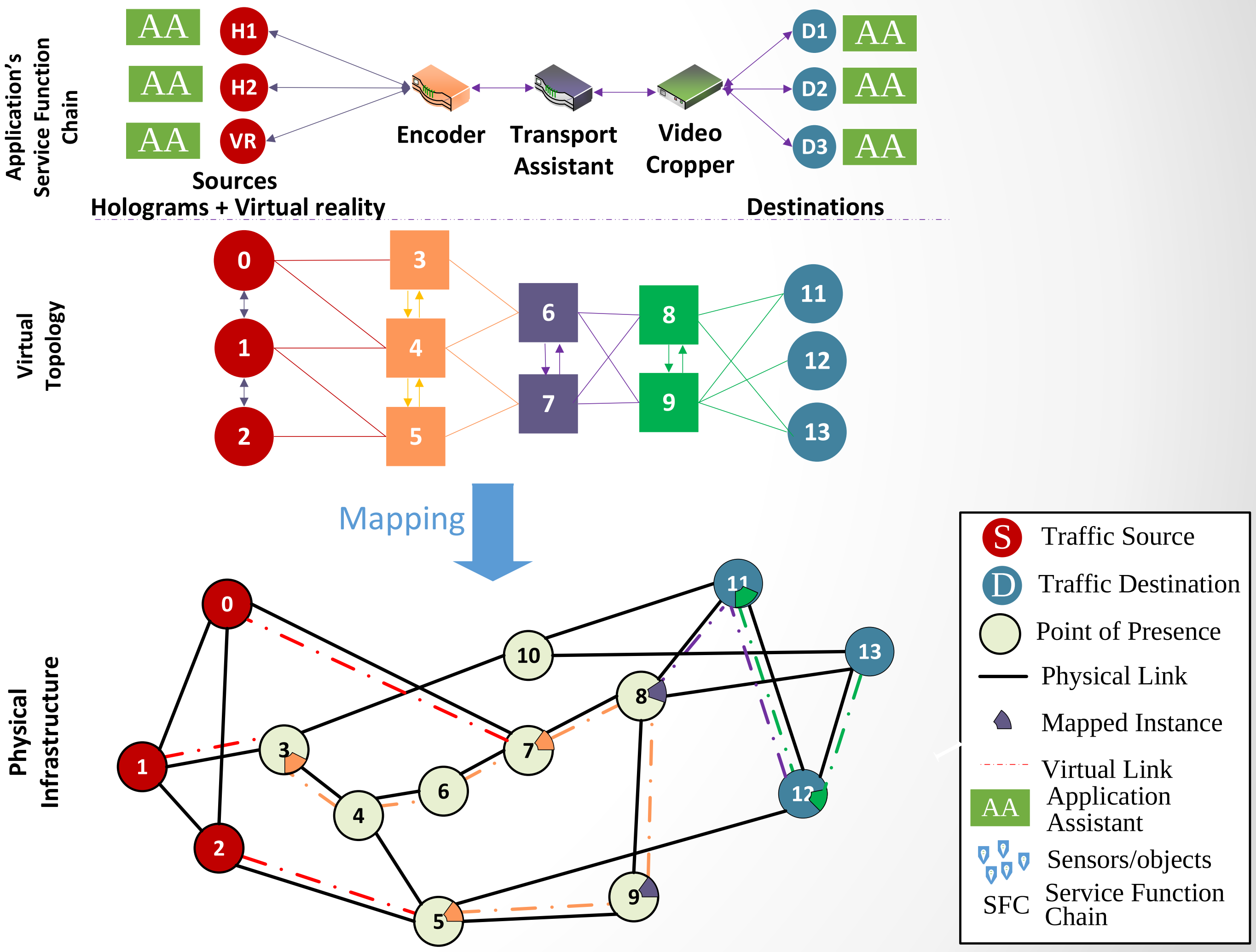

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- Multiple source destination Service Function Chains
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- Designing Service Function Chains tailored to applications
- High-performance softwarized functions
- Signaling
- Resource Allocation
- Fault-tolerance and Failure Management
- High-Precision and Fine-grained Monitoring and Measurements
- SDN++
- Distributed Cross-Layer Transport Protocol (sockets, caching, communication)
- Security and Privacy

Details are available in the paper (https://arxiv.org/abs/1905.07137)

Transport Layer Protocols (cont)

QUIC

- Transport over UDP
- Multi-streaming:
  - Every stream is a **reliable** bidirectional bytestream
  - Multiplexed streams between **two endpoints**
  - Stream prioritization
- Flow-control and congestion control very similar to TCP
- Endpoints use Explicit Congestion Notification (ECN)

SCTP

- Basically, a TCP++
- Multi-streaming
- Unordered delivery is possible
- Flow control and congestion control similar to TCP

Transport Layer Protocols (cont)

What are the limitations of SCTP and QUIC?

- E2E communication: multiple flows (streams) of the same application may connect more than two end-points
- A blind congestion control
- No support from the network: the network knows better about its state

→ Can better locate and manage congestion
→ Predict and detect more efficiently congestions/failures/problems…
→ Can retransmit faster
→ Can provide better garantees in terms of delay and packet loss

Network Protocol Stack/Functions Transport Assistant (cont)

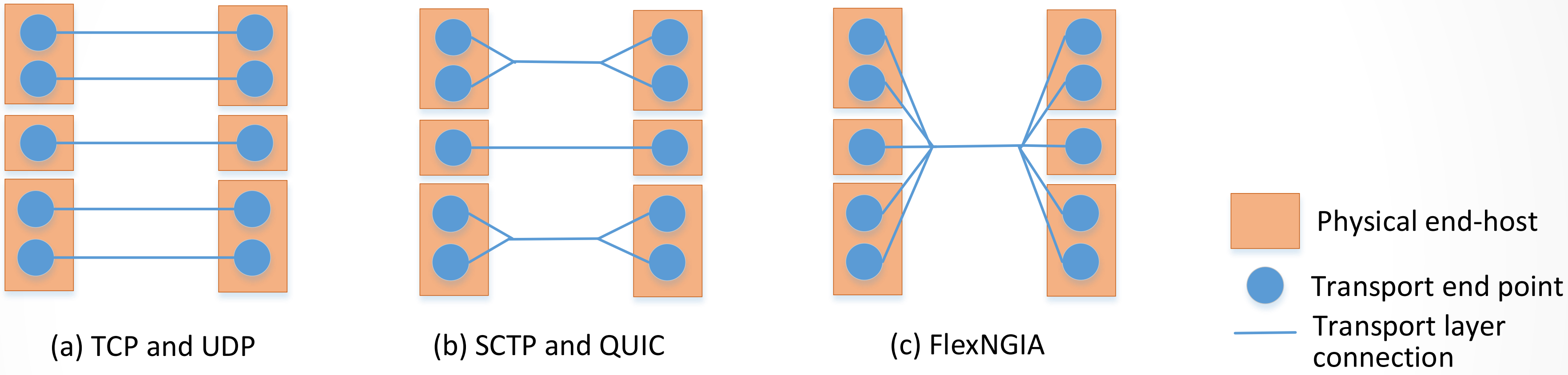

Illustration of how one single network application might be seen at the transport Layer

- Transport Assistants manage all these flows while taking into account that they all belong to the same application
- TAs monitor these flows, divide the total bandwidth allocated for the application among them.