

Learning Outcomes

- Learn the names of the top network and ISP providers
- Understanding basic networking concepts
- Grasp the basics of Network Functions Virtualization (NFV)
- Grasp the basics of Software Defined Networks (SDN)
- Learn the names and basic information on the leading long-range and short-range wireless protocols



Network Topics

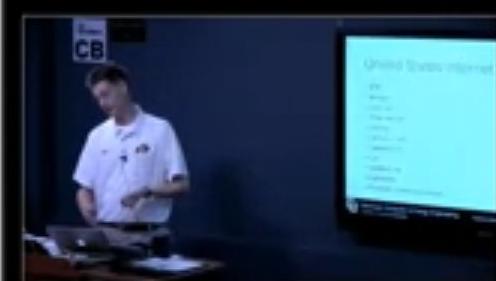
Internet Service Providers

- Networks
 - Survey of leading providers
 - Network terminology and topologies
 - Network Functions Virtualization (NFV)
 - Software Defined Networks (SDN)



United States Internet Service Providers

- AT&T
- Verizon
- Comcast
- Time Warner
- Charter
- Century Link
- CableVision
- Cox
- SuddenLink
- CableOne
- Frontier Communications





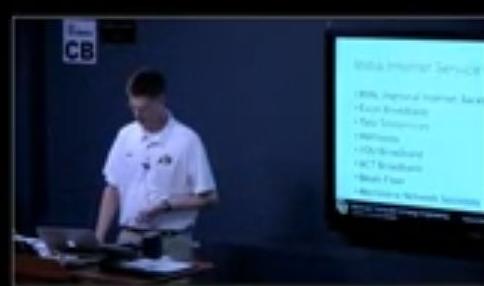
European Internet Service Providers

- Vodafone
- Tele Columbus
- TIM
- Infostrada
- Ono
- Altibox
- Virgin Media



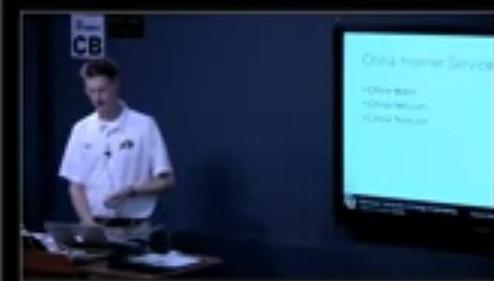
India Internet Service Providers

- BSNL (National Internet Backbone)
- Excel Broadband
- Tata Teleservices
- Hathaway
- YOU Broadband
- ACT Broadband
- Beam Fiber
- Micronova Network Solutions



China Internet Service Providers

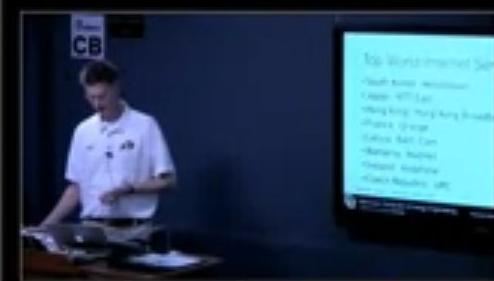
- China Mobil
- China Netcom
- China Telecom



Top World Internet Service Providers

- South Korea: HelloVision
- Japan: NTT East
- Hong Kong: Hong Kong Broadband Network
- France: Orange
- Latvia: Balti-Com
- Romania: Madnet
- Ireland: Vodafone
- Czech Republic: UPC

Source: <http://uswww.rediff.com>



Top World Players in Cellular IoT Market

- 1 Qualcomm Inc. (U.S.),
- 2 Gemalto N.V. (Netherlands),
- 3 Sierra Wireless (Canada),
- 4 U-Blox Holding AG (Switzerland),
- 5 MediaTek Inc. (Taiwan),
- 6 Telit Communications PLC (U.K.),
- 7 ZTE Corporation (China),
- 8 Mistbase (Sweden),
- 9 Sequans Communications (France)
- 10 CommSolid GmbH (Germany)

Source: Markets and Markets



Network Terminology



- **Store and Forward Switching**
 - Pre-dates computers, point-to-point teleprinter equipment
 - Stored on punched paper tape
 - Humans read the address
 - Then forwarded to recipient
- Modern use: An entire packet is received, checked for errors and then forwarded
 - Used in delay-tolerant applications or where intermittent communication is acceptable
 - Not applicable to real-time systems



Network Terminology (con't)

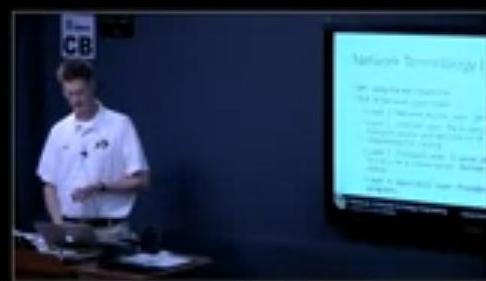
- **Cut Through Switching**

- A switch starts forwarding a packet once the destination address is received
- If the end CRC check fails, a marker/symbol at the end of the packet is set to indicate the failure.
- Greatly reduces latency
- Applicable to real-time systems



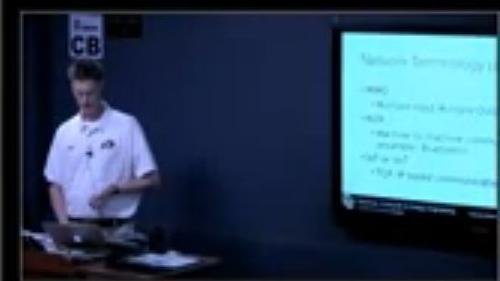
Network Terminology (con't)

- DPI: Deep Packet Inspection
- TCP/IP Network layer model:
 - Layer 1: Network Access layer: Defines how data is physically sent.
 - Layer 2: Internet layer: Packs data into packets known as datagrams. Contains source and destination IP address. This layer is also responsible for routing.
 - Layer 3: Transport layer: Enables devices at the source and destination to carry on a conversation. Defines the level of service and connection status.
 - Layer 4: Application layer: Provides APIs and protocols to application programs.



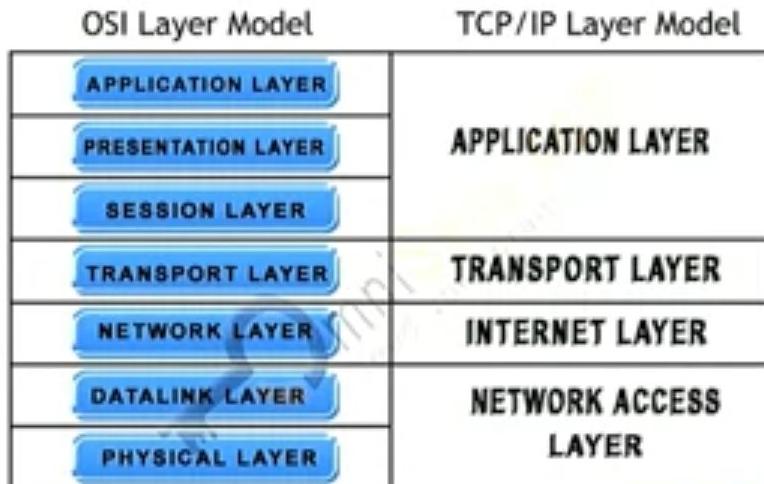
Network Terminology (con't)

- MIMO
 - Multiple Input Multiple Output
- M2M
 - Machine-to-machine communication, non-TCP/IP based
(example: Bluetooth)
- IoT or IIoT
 - TCP/IP based communication





Network Terminology (con't)



Source: <http://www.omnisecu.com>



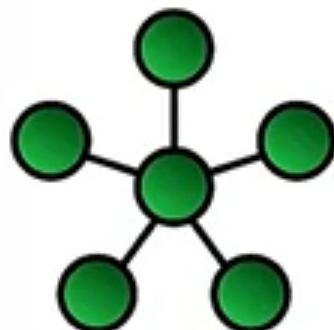
Network Topologies

- **Physical topology** refers to the cabling (or wireless connections), node locations and interconnections between nodes. The physical topology is driven by the level of control, fault tolerance and cost required.
- **Logical topology** refers to the way data is passed through a network from one node to the next.

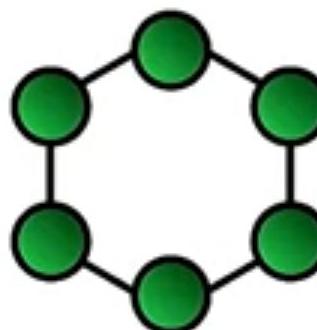


Network Topology Examples

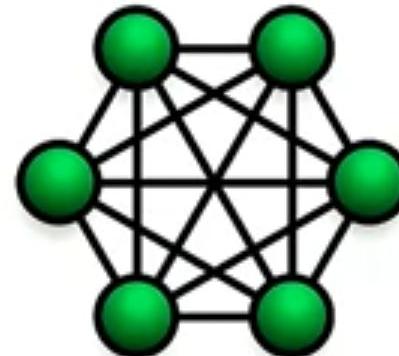
Star



Ring



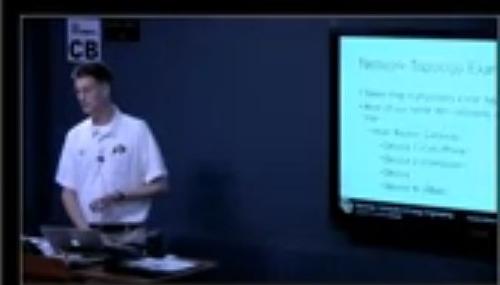
Full-mesh



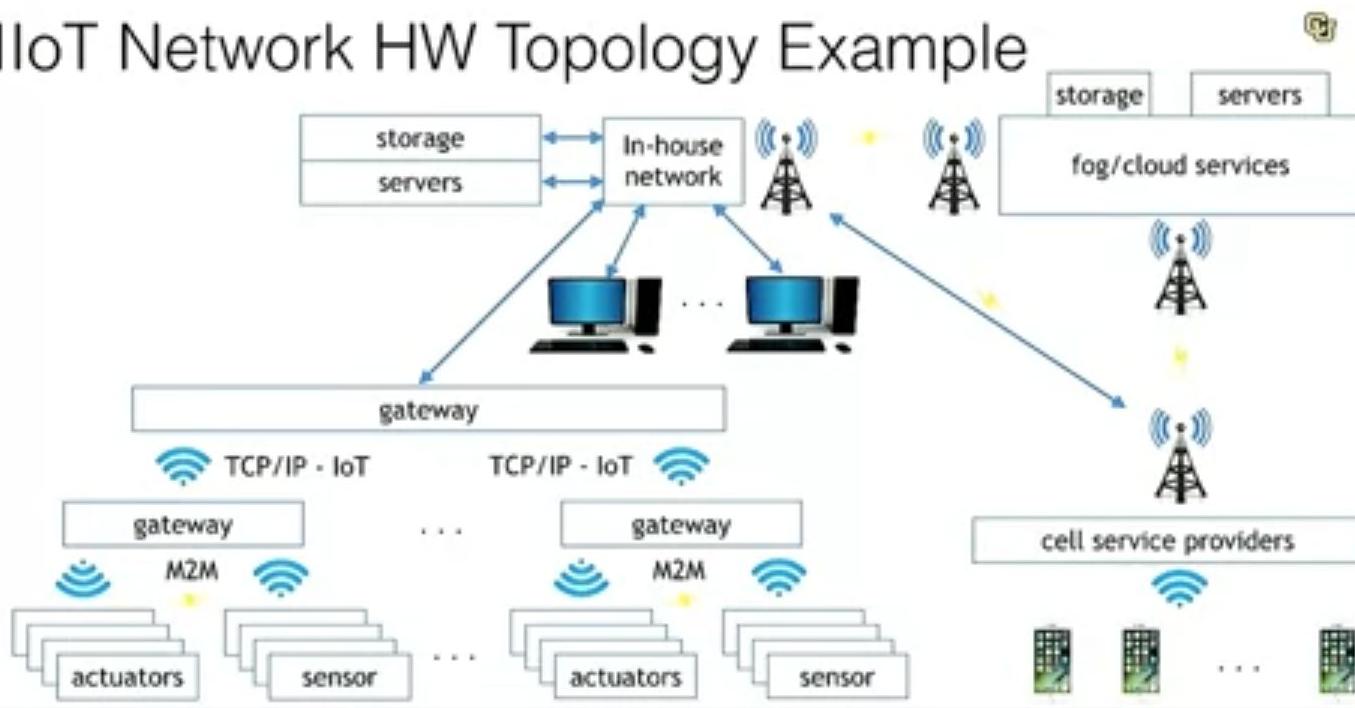
Source: https://en.wikipedia.org/wiki/Network_topology

Network Topology Examples

- Token ring is physically a star topology, but operates as a ring
- Most of our home Wifi networks are physically and logically a star:
 - Hub/Router/Gateway
 - Device 1 (Cell Phone)
 - Device 2 (Computer)
 - Device ...
 - Device N (XBox)



IIoT Network HW Topology Example



Network Functions Virtualization

- <https://www.youtube.com/watch?v=SIKxuFsx1l0>
- <https://www.youtube.com/watch?v=pxQAL-gxiNk>
- <https://www.youtube.com/watch?v=imkJOobsfxE>
- NFV allows network operators to dynamically place (or move) networking capability as usage demands change.



Network Functions Virtualization

**Alan Talks Tech on Network Functions Virtualization
(NFV)**



www.Spirent.com
[YouTube "alantalkstech"](https://www.youtube.com/user/alantalkstech)
<http://alantestwiki.cbworks.com>



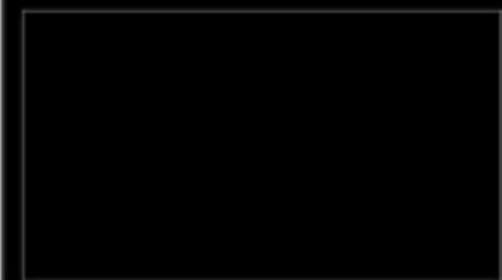
Network Functions Virtualization

**Network Functions
Virtualization
(NFV)**





Network Functions Virtualization



Network Functions Virtualization

Network Functions



Network Functions Virtualization

Network Functions

- Inflexible
- Costly
- High Power
- Truck Rolls
- Complex

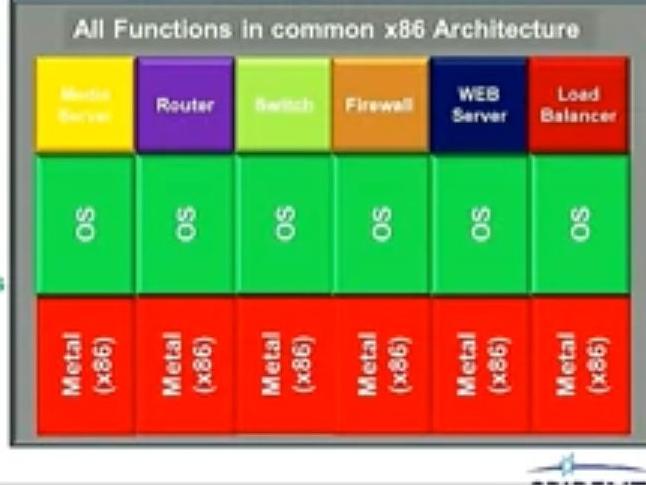


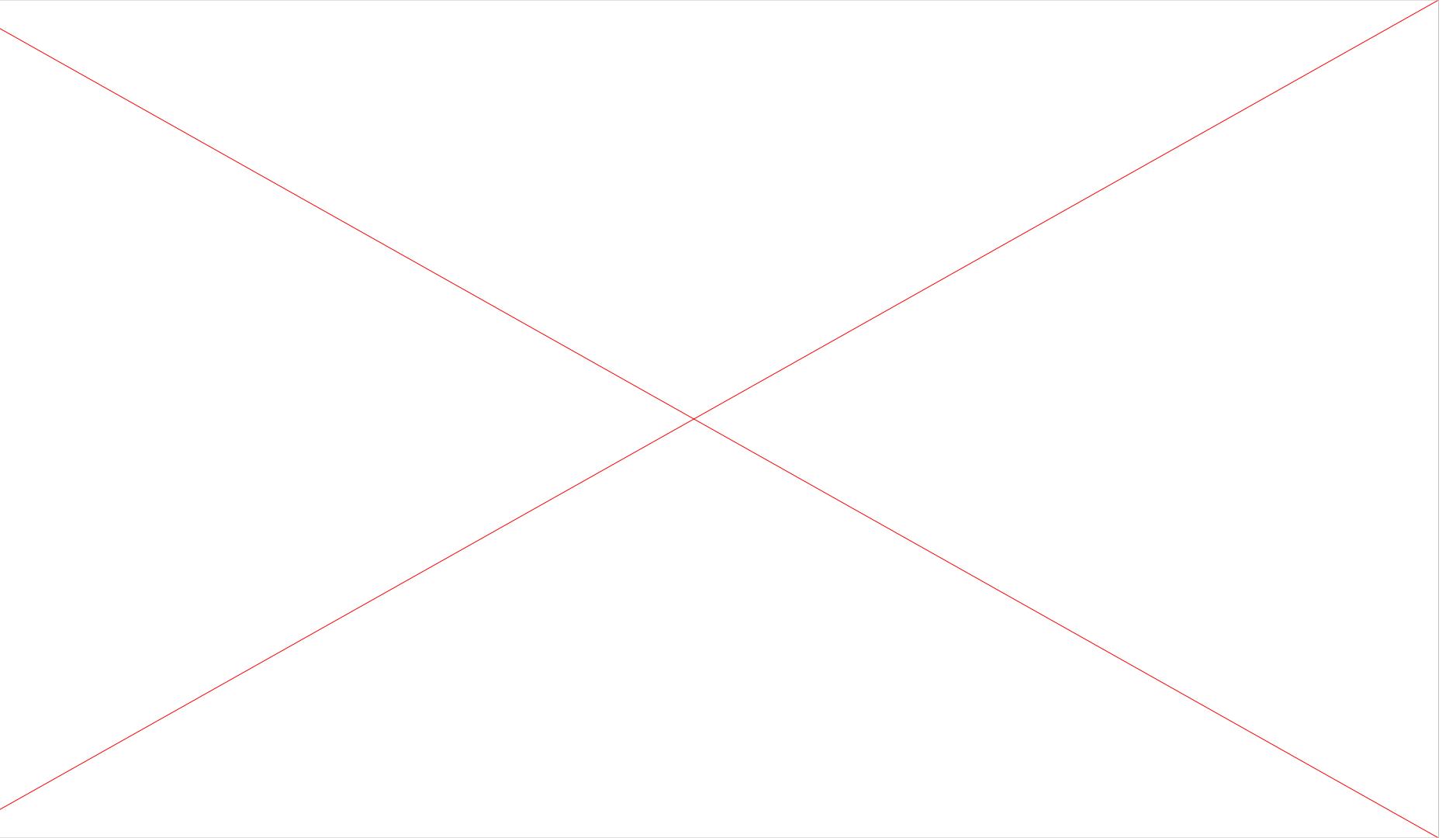
Network Functions Virtualization

Network Functions Virtualization (NFV)

- Standard Hardware
- Less Complex
- Very Flexible
- Reduced Power
- Lower CapEx
- Lower OpEx
- Test new apps
- Low risk
- Reduced TTM
- Open Market to Software suppliers

Using Blade Server





Network Functions Virtualization

"SDN and OpenFlow World Congress: Darmstadt-Germany
October 22-24, 2012. A new committee set up under ETSI



Network Functions Virtualization



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This Module: The (Near) Future of SDN

- ◉ Two Lessons
 - SDN for network, compute, storage: NFV
 - Open Problems and Challenges



Network Functions Virtualization



Middleboxes are Pervasive: What Does SDN Have to Say About It?

- Networks have firewalls, IDS, VPN gateways, WAN optimizers, etc.
- SDN promises centralized management of the forwarding parts of the data plane
- Can it be a unifying framework for a more general set of functions?



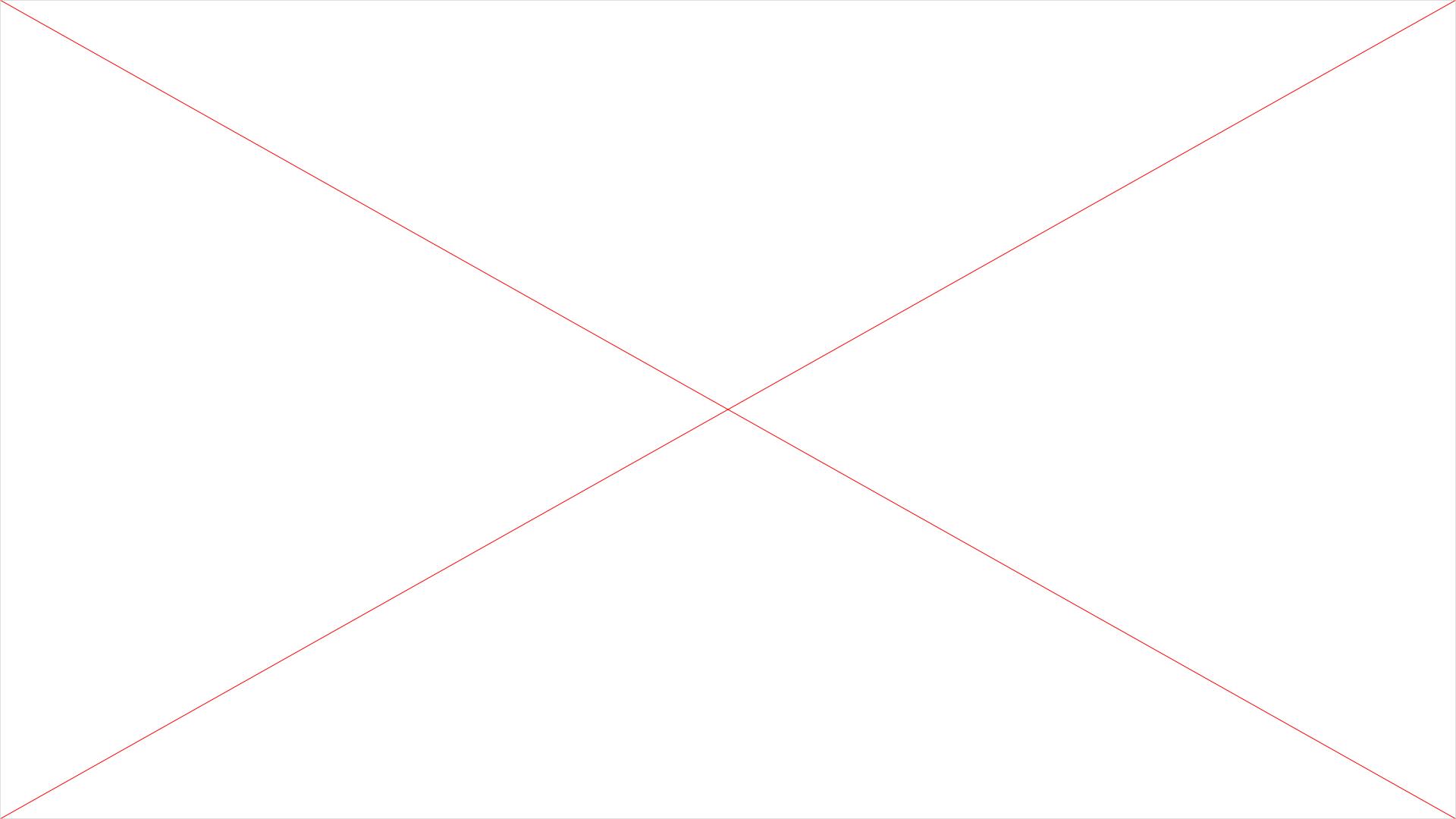
Network Functions Virtualization



Why Placement and Steering are Hard

- Need to map traffic flows and demands to
 - Available network resources (i.e., paths)
 - Available processing capacity (i.e., middleboxes)
- Need a unified abstraction for control, data, and storage





Network Functions Virtualization



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Slick Elements

- Arbitrary code
 - Functions implement Slick API
 - Raises triggers at controller

- Self-describing manifest
 - Hardware requirements
 - List of exposed triggers
 - Network requirements:
flow affinity: needs to see both sides of traffic, or all traffic from a host



Network Functions Virtualization

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Slick Application

- Implements network policies
 - What element to run on which traffic
 - How to react to changes in network conditions

- Does not specify
 - Where to place the element
 - How traffic should be routed

Smart Virtual Switch
Programmable device:
NetFPGA, x86 server



Network Functions Virtualization



Slick Controller

- Manages and configures network of middleboxes
 - Implements resource discovery
 - Deploys/removes elements on machines
 - Ensures element availability in the face of failures

- Implements policy in an application
 - Automates element placement and traffic steering
 - Uses online resource allocation algorithm



Network Functions Virtualization

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Application: Dynamic Redirection

- Inspect all DNS traffic with a DPI device
- If suspicious lookup takes place, send to traffic scrubber

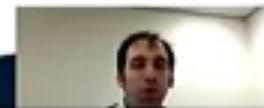


Network Functions Virtualization

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Solution Goals

- Minimize policy implementation footprint.
- Enable optimization for bandwidth, latency, and network resources minimization.



Network Functions Virtualization



Placement Problem

- **Problem:** Given flowspace to element graph mapping, place element graph inside the network such that network resource utilization can be optimized.
- The problem of placement has three goals:
 - Minimize the number of locations to place the elements.
 - Minimize the bandwidth utilization while implementing policy.
 - Minimize the latency of the flows while implementing policy.

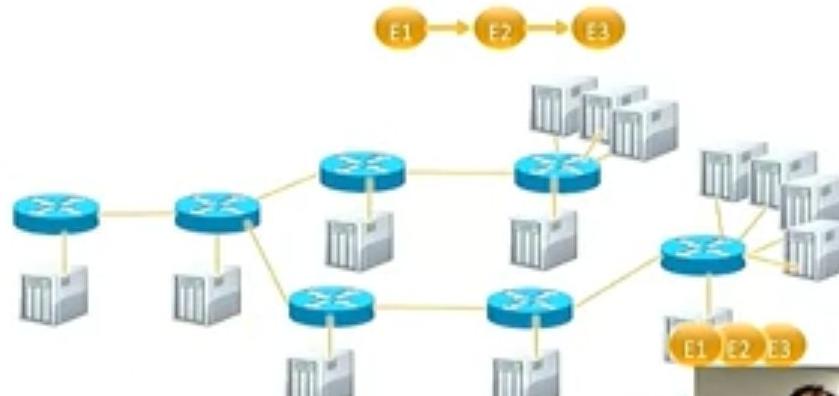


Network Functions Virtualization



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Placement Problem

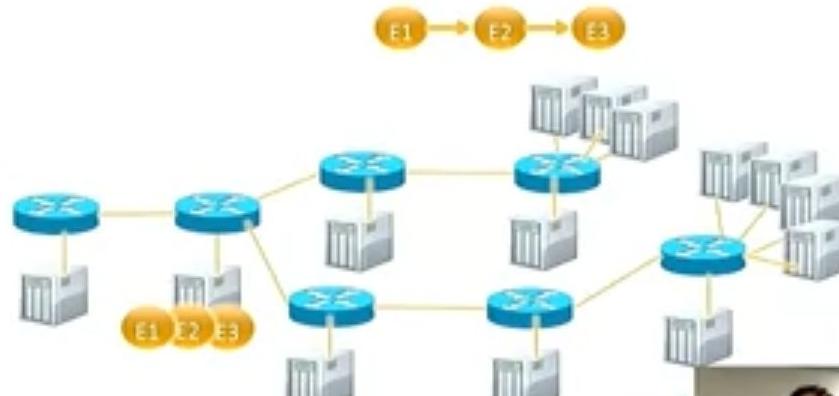


Network Functions Virtualization



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Placement Problem

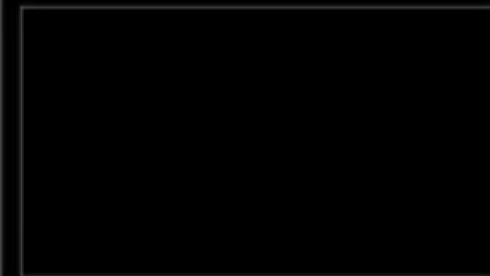
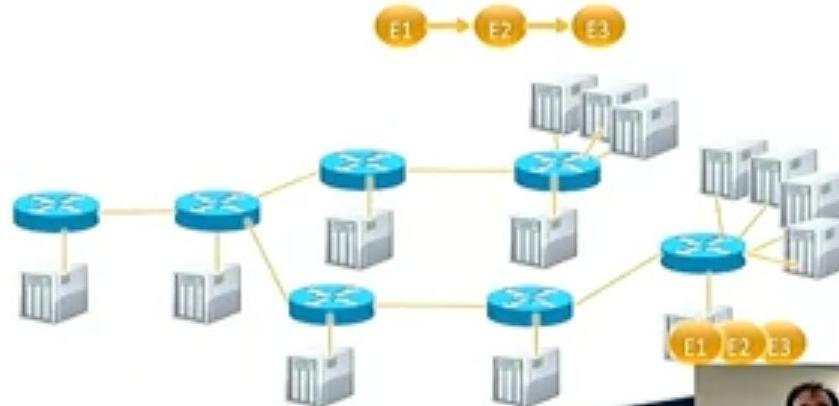


Network Functions Virtualization



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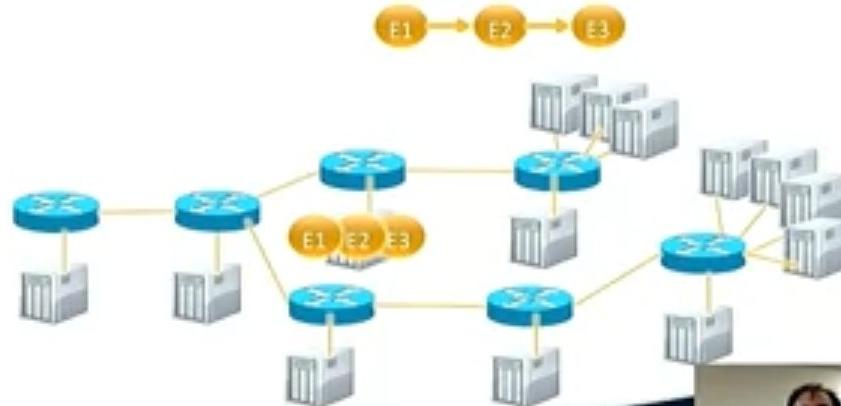
Placement Problem



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Placement Problem

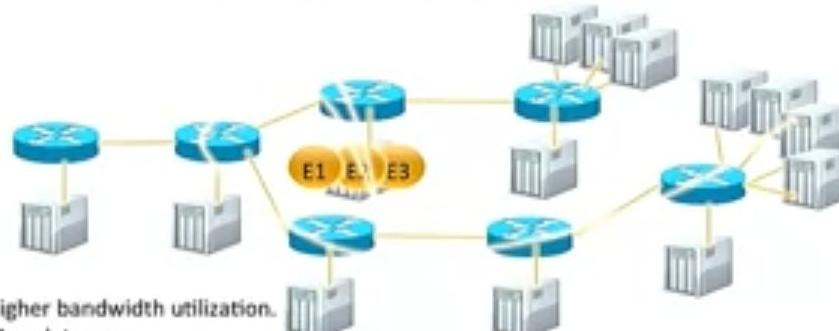


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Wrong Placement Impact

[dst_ip=y.y.y.*]



- Higher bandwidth utilization.
- More latency.
- More switch resources.



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Steering

- Element A
- Element B



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Steering Properties

- Finding shortest path is not the only requirement.
- Steering needs to have following properties apart from shortest path steering.
 - Consistent Ordering
 - Chaining
 - Asymmetric Steering
 - Dynamic Chains
 - Load Awareness



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Dynamic Chains

- Enable path changes for packet flows based on certain conditions.
 - All incoming flows with specific destination IP range should pass through stateful firewall and DPI and if certain traffic is detected send traffic



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Place and Steer

- Continuously monitors link and machine loads.
- In case of overloaded elements, creates new element instance.
- Steering triggers placement in case of loads.
- Reclaims element instances that are not being used.



Network Functions Virtualization



Summary

- Need a framework that tackles following three problems:
 - Enable Network Function Virtualization in an SDN environment. (Programming Model)
 - Where to place the functions inside the network. (Placement)
 - How to steer the traffic through these functions. (Steering)
- Need algorithms and abstractions!

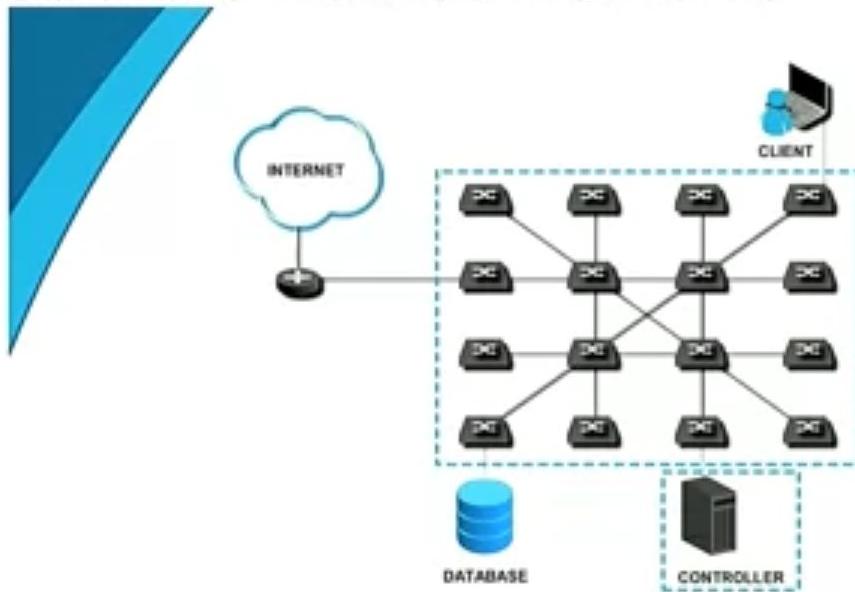


Software Defined Networks

- https://www.youtube.com/watch?v=lPL_oQT9tmc
- <https://www.youtube.com/watch?v=vohyzHE3BpU>
- SDN typically divides network functions into data and control and provides the mechanisms to dynamically determine how network traffic flows through a network.



Software Defined Networks



4