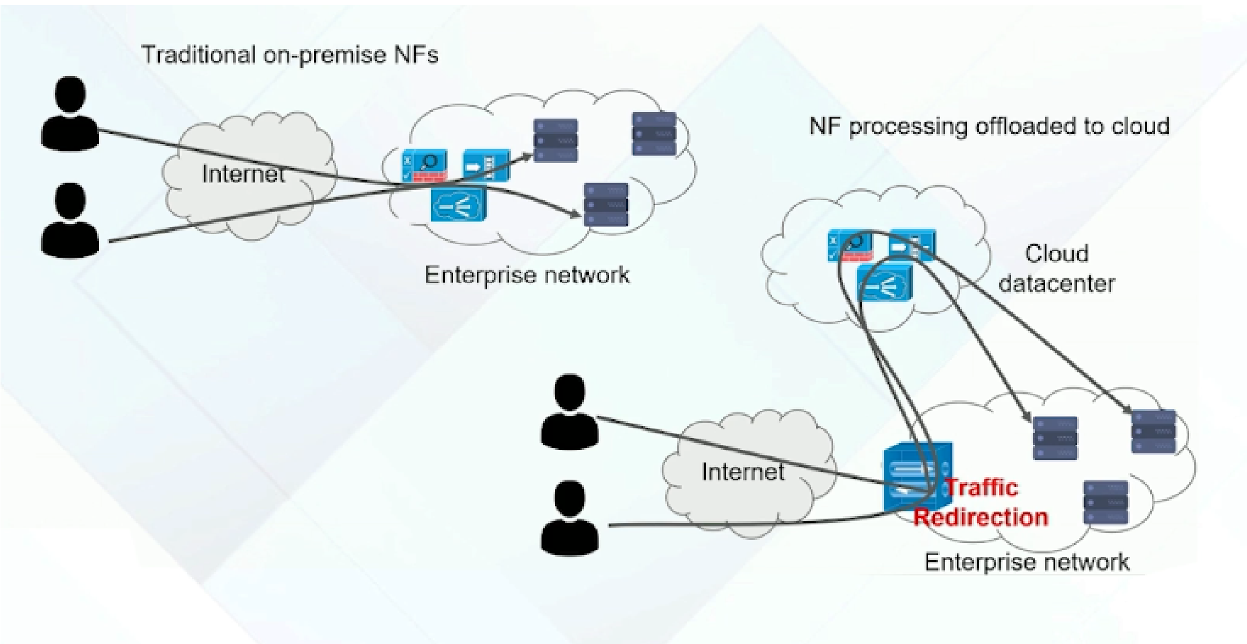
NFV on Public Cloud

Introduction

1. Middleboxes are typically deployed on premise which led to the practice of deploying NFV applications on on-premise clusters as well
   - Growth of public cloud makes migrating these services appealing due to reducing management costs
   - Techniques for offloading NFV workload to a managed cloud as well as other developments in the telecom industry that makes offloading NFV applications viable

Benefits of using Managed Cloud Services

1. Offloading NFs to the cloud



Offloading Middlebox Processing to the Cloud

2. Why offload NF processing to the cloud?
   - Leverage economy of scale to cut costs
   - Simplify management
     - No need for training personnel
     - Upgrades are handled by cloud provider
     - Low-level configuration of NFs is replaced by policy configurations
       * Avoid failures due to misconfiguration
   - Elastic scaling
     - Scale in/out works much better on cloud vs on premise
       * Avoid failures due to overload

Techniques for Offloading NF to Managed Cloud

1. Important questions to answer
   - How is the redirection implemented?
     - Functional equivalence needs to be maintained

    - Latency should not be inflated
  - How to choose cloud provider to offload to?
    - Dependent on cloud provider's geographical resource footprint
2. Bounce redirection
   - Simplest form of redirection
   - Tunnel ingress and egress traffic to the cloud service
   - Benefit: Does not require any modification to the enterprise or the client applications
   - Drawback: Extra round trip to the cloud
     - Can be feasible if cloud point-of-presence is located close to the enterprise
3. IP Redirection
   - Save extra round-trip by sending client traffic directly to the cloud service
   - Cloud service announces IP prefix on behalf of the enterprise
   - Drawback: multiple point-of-presence (PoP)
     - Cannot ensure that same PoP receives both flows a -> b and b -> a
       * There is not a guarantee about which PoP ends up receiving client's packets since all PoPs advertise the same IP address range
     - Since traffic is directed using Border Gateway Protocol (BGP), no guarantee of selecting PoP that minimizes end-to-end latency
4. DNS-based Redirection
   - Cloud provider runs DNS resolution on behalf of enterprise
   - Enterprise can send reverse traffic through the same cloud PoP as forward traffic
     - Gateway looks up destination cloud PoP's IP address in DNS service
   - Drawback: Loss of backwards compatibility
     - Legacy enterprise applications expose IP addresses to external clients (not DNS names)
5. Smart Redirection
   - For each client c and enterprise site e,
     - Choose the cloud PoP P(c,e) such that
       * P(c,e) = argmin(latency(P,c) + latency(P,e))
   - Requires the enterprise gateway to maintain multiple tunnels to each participating PoP
     - Cloud service computed estimate latencies between PoPs and clients/ enterprises using IP address information
6. Latency Inflation due to Redirection
   - Original latency = Host 1 -> Host 2
   - Inflated latency = Host 1 -> Cloud PoP -> Host 2
   - More than 30% of host pairs have inflated latency < original latency
     - Triangle-inequality is voilated in inter-domain routing
     - Cloud providers are well connected to tier-1/tier-2 ISPs

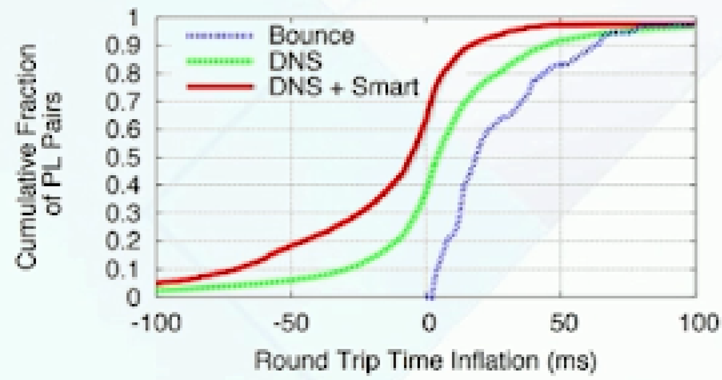


Figure 6: Round Trip Time (RTT) inflation when redirecting traffic between US PlanetLab nodes through Amazon PoPs.

Redirection Latency

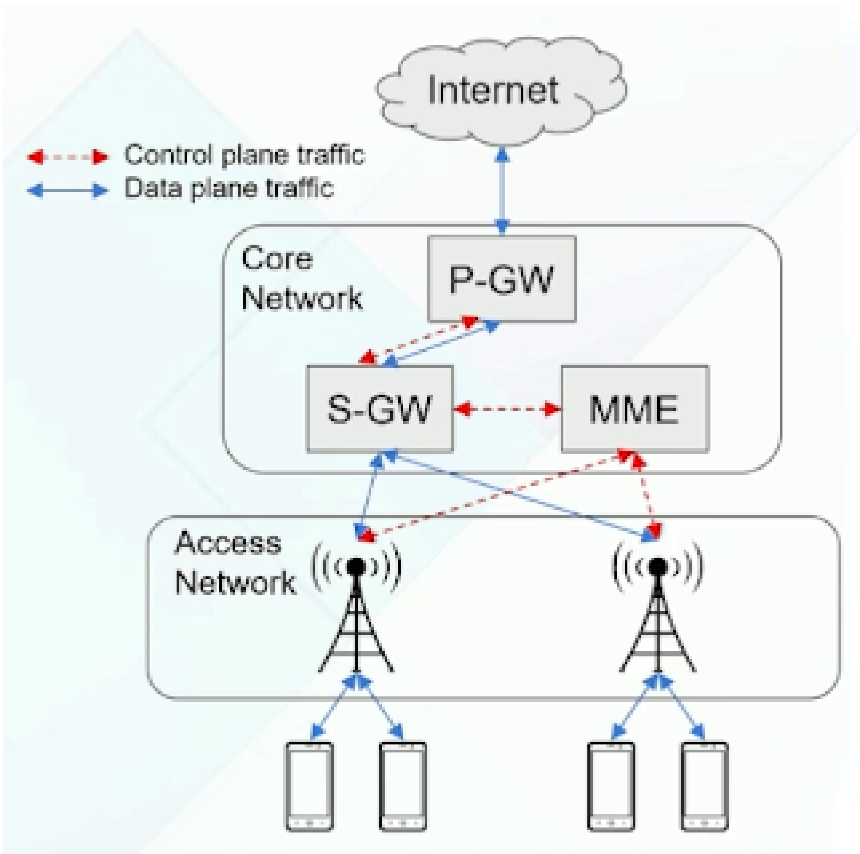
Observed Performance of NF Offloading

1. What about bandwidth savings?
   - Middleboxes like Web Proxy, WAN accelerator are used to limit WAN bandwidth used by enterprise
     - HTTP proxy limits WAN bandwidth usage by caching web pages
   - If we move them to the cloud, WAN bandwidth becomes high for the enterprise
   - Safest solution is to not migrate those types of middleboxes
2. What about bandwidth savings?
   - Solution: Use general-purpose traffic compression in cloud-NFV gateway
   - Protocol agnostic compression technique achieves similar bandwidth compression as the original middlebox
3. Which cloud provider to select?
   - Amazon-like footprint
     - Few large PoPs
   - Akamai-like footprint
     - Large number of small PoPs
   - Emerging "edge-computing providers"
4. Telecom providers are ideal for edge computing
   - Telecommunication providers like AT&T and Verizon posses a geographical footprint much denser than AWS or Akamai
   - Residential Broadband service providers use functions like virtual Broadband Network Gateway (vBNG)
     - To provide residential broadband users with services like subscriber management, policy/QoS management, DNS, routing
     - Service providers also offer services like Video-on-Demand CDN, virtual Set Top Box
   - Such services are deployed close to the subscribers
     - These compute resources are potential candidates for offloading
5. OpenCORD Initiative
   - Telecommunication providers own central offices
     - Contain switching equipment
   - OpenCORD: Central Office Re-architected as a datacenter
   - Setting up central offices with general purpose servers
   - Provides infrastructure services

    - Deploy their own network functions
    - For 3rd parties to deploy NFV functions
  - Allow enterprises to host network functions on virtualized hardware
    - Colocated with telecom providers' network functions
  - This becomes a candidate realization of mobile edge computing
    - Good incentive for infrastructure owners to virtualize their infrastructure
6. Remote sites require illusion of homogenous network
  - Organizations like Chick Fil A or Honeywell have geo-distributed sites
    - Each site needs multiple network services
    - Firewalld, IDS, Deep Packet Inspection, HTTP Proxy, WAN optimizer
  - Used to be implemented on custom hardware on-premise
    - Can be offloaded to a managed service
7. Virtualized customer premise equipment (CPE)
  - Serves as a gateway for multiple parts of an Enterprise Network to connect to each other
  - Placed in Edge PoP or centralized datacenter
  - An industry solution for migrating NFV to a cloud service

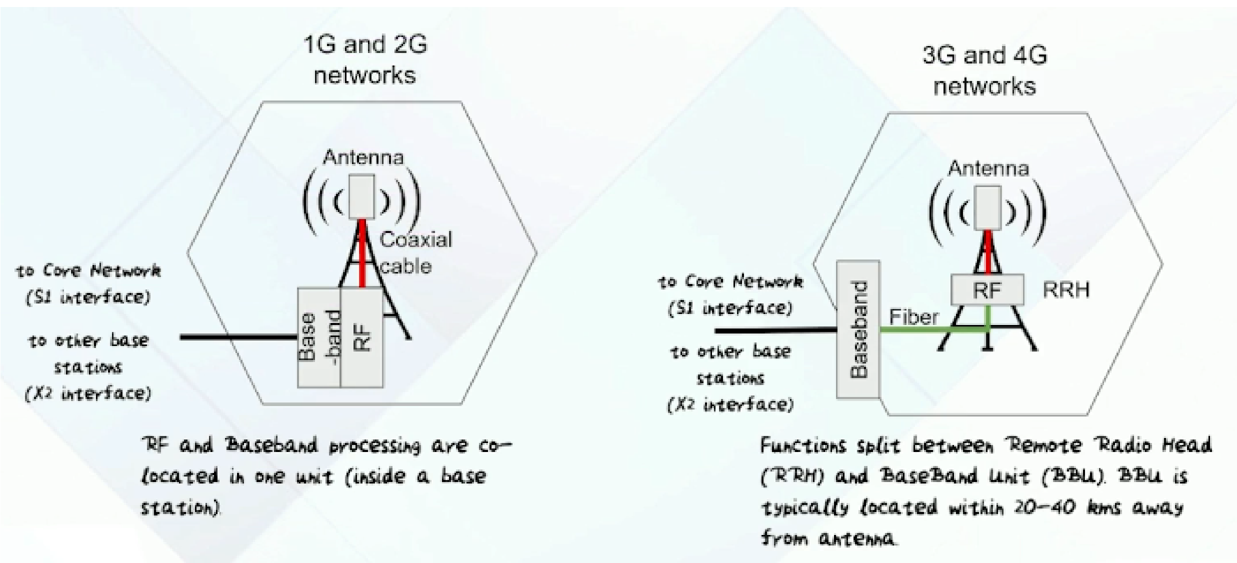
Mobile Edge Computing

1. NFs in Cellular Networks
  - Another evolution that is happening that is moving NFv to managed infrastructure
    - Converting RAW cellular packets to IP ready packets
  - Different from earlier middleboxes (which were meant for IP packets)
2. Building blocks of a cellular network
  - Access network
    - Consists of base stations (evolved NodeB - eNodeB)
    - Acts as interface between end-users (user equipment/UE) and core network
    - MAC scheduling for uplink and downlink traffic
    - Header compression and user-data encryption
    - Inter-cell Radio Resource Management
  - Core network
    - Mobility control -> making cell-tower handoff decisions for each user (Mobility Management Entity - MME)
    - Internet access -> IP address assignment and QoS enforcement (Packet Data Network Gateway - P-GW)
    - Packet routing to PGW and anchor point during inter-base station handover (Serving Gateway - S-GW)



Cell Network

3. Traditional Radio-Access Networks
   - Packet processing in access network perform 2 types of tasks
     - Analog radio funciton processing (RF processing)
       * Digital-to-analog converter/Analog-to-digital converter
       * Filtering and amplification of signal
     - Digital signal pcessing (Baseband processing):
       * L1, L2, and L3 functionality

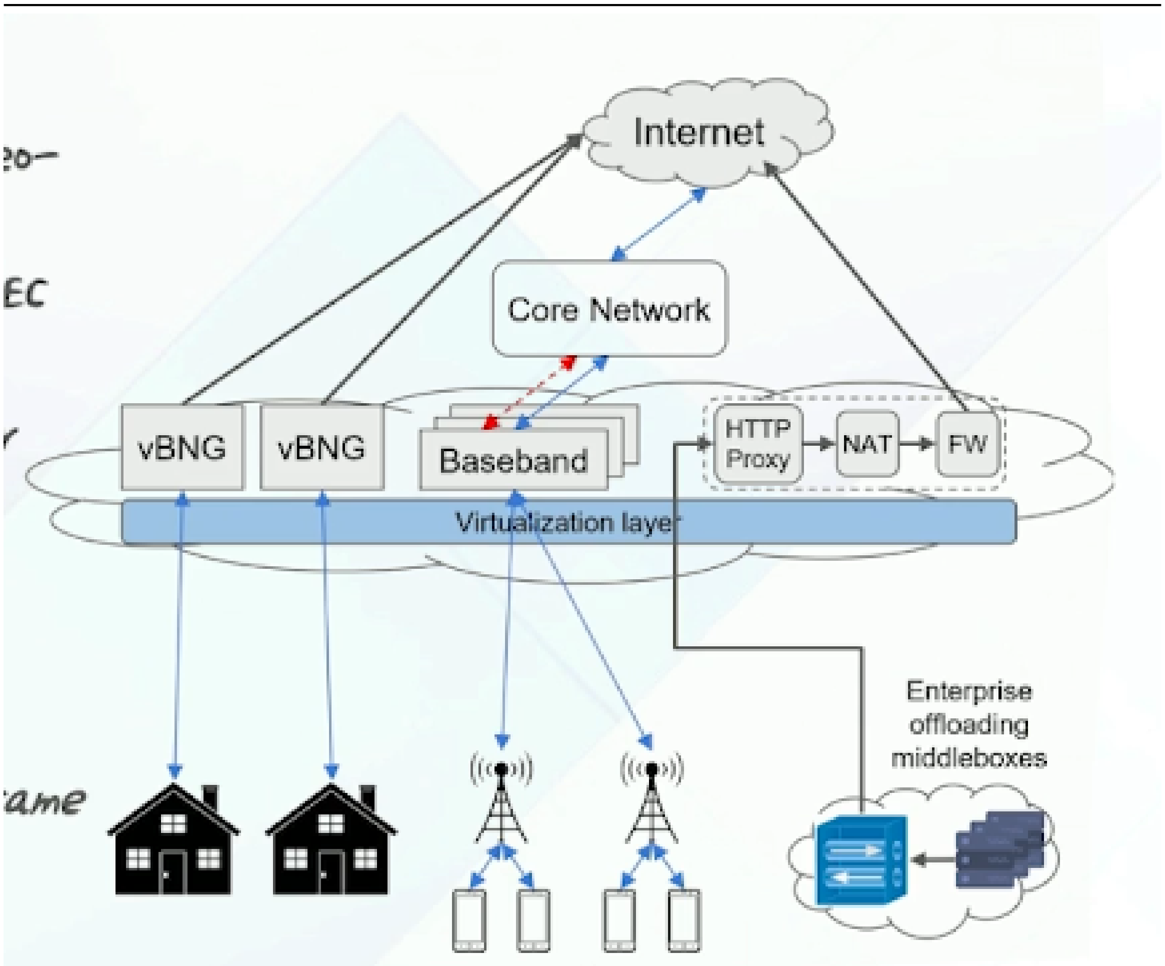


Evolution of Base Stations

4. Benefits/Limitations of 3G/4G Design
   - Benefits:
     - Lower power consumption since RF functionality can be placed on poles and rooftops -> efficient cooling
     - Multiple BBus can be placed together in a convenient location -> cheaper maintenance
     - One BBU can serve multiple RRHs
   - Limitations:
     - Static RRH-to-BBU assignment -> Resource underutilization
     - BBUs are implemented as specialized hardware -> poor scalability and failure handling

Cloud Radio Access Network (RAN)

1. Cloud Radio Access Network
   - Virtualizes the BBUs in a BBU pool
   - Base-band unit now implemented as software running on general purpose servers
   - Allows elastic scaling of BBUs based on current workload
   - BBU-RRH assignment is dynamic, leading to higher resource utilization
2. Location of virtual BBU pool
   - Splitting radio function and base band processing poses stringent requirements on connecting links
     - Low latency
     - Low jitter
     - High throughput
   - Need compute capacity in physical proximity of deployed base stations
     - Geo-distributed computing infrastructure
     - Virtualization support required for scalable network processing
3. The complete picture
   - Cellular network providers setup geo-distributed MEC capacity
     - MEC: Mobile edge computing
   - C-RAN functions are deployed on MEC servers
   - MEC capacity is made available for enterprises to offload their NFs
   - Unifying of IP-level network functions and the RAN-level NFs
     - All of them are being deployed on the same managed infrastructure



Cloud Radio Access Network

Conclusion

1. Discussed how virtual NFs can be moved to manage cloud infrastructures of service providers