Motivating Mobile Edge Cloud Platforms and using Network Function Virtualizaiton

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A Middlebox World

ad insertion

BRAS

WAN accelerator

carrier-grade NAT

transcoder

session border controller

IDS

load balancer

DDoS protection

firewall

QoE monitor

DPI

Motivation of Middleboxes

- Why did each of them come to exist and what are the resulting problems?
  - NAT
  - Firewalls
  - Load balancers
  - Rate Limiters
  - Traffic accelerators
  - Caches
  - Proxies
  - DPI

A solution for network evolution in response to changing performance, security and policy compliance requirements

currently a critical pervasive piece of the network infrastructure

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Middleboxes

- Currently, most of the functionality is implemented in purpose built network appliances
  - Costly
  - Hard-to-modify dedicated hardware
- Makes it difficult for the network to
  - Evolve
  - Adapt to changing traffic requirements

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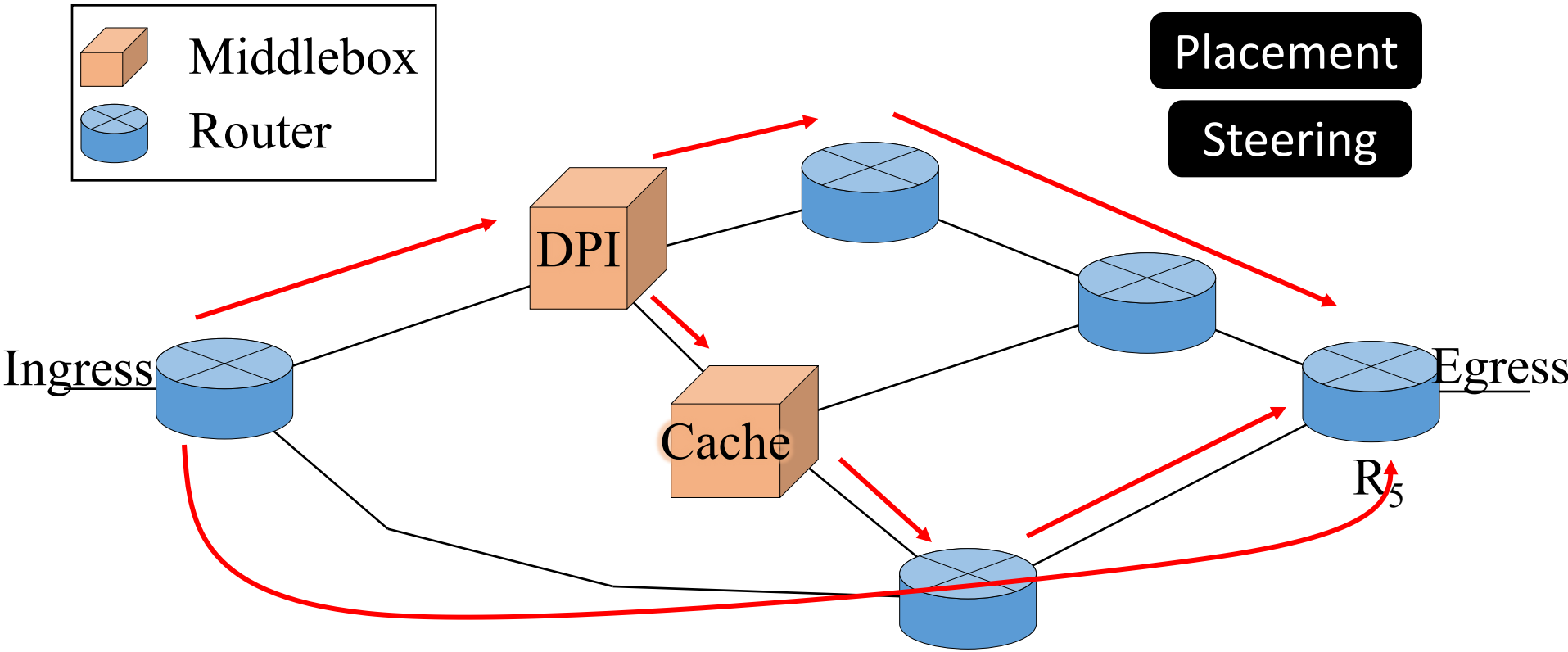
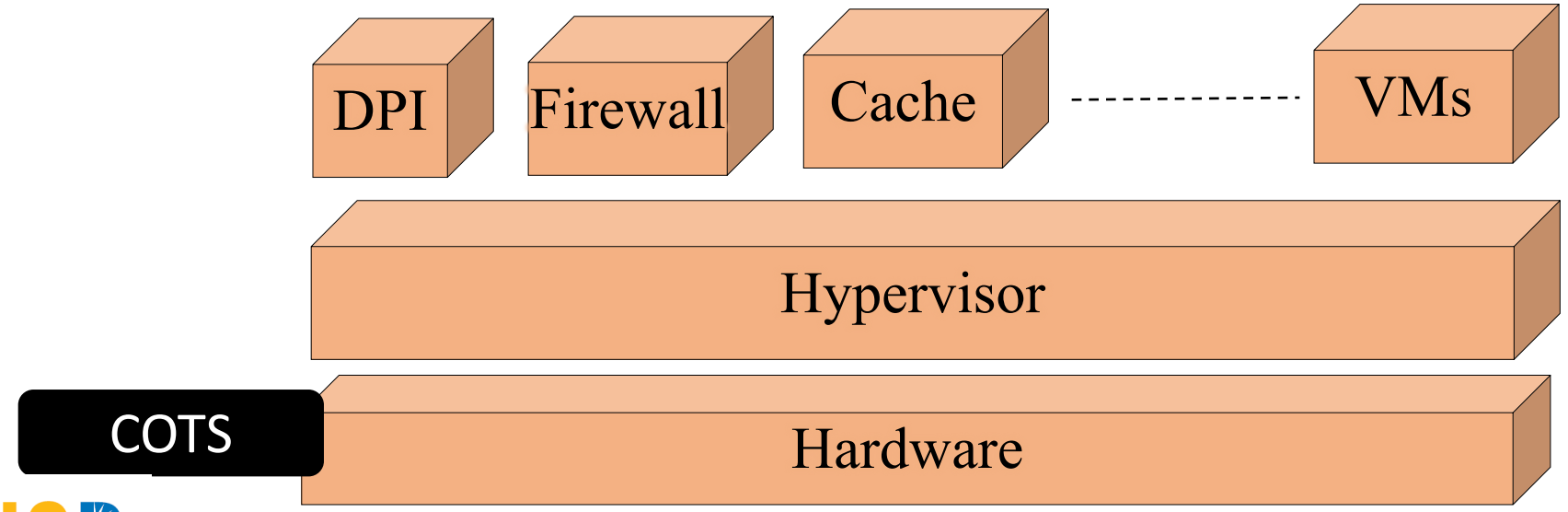
Middleboxes

- They have to be resident on the path of the flow
  - Flow might have to deviate from the shortest IP path



Network Function Virtualization (NFV)

- Shift from dedicated hardware to software-based processing
- Runs on virtualized, shared platforms built on commodity hardware servers, switches and storage



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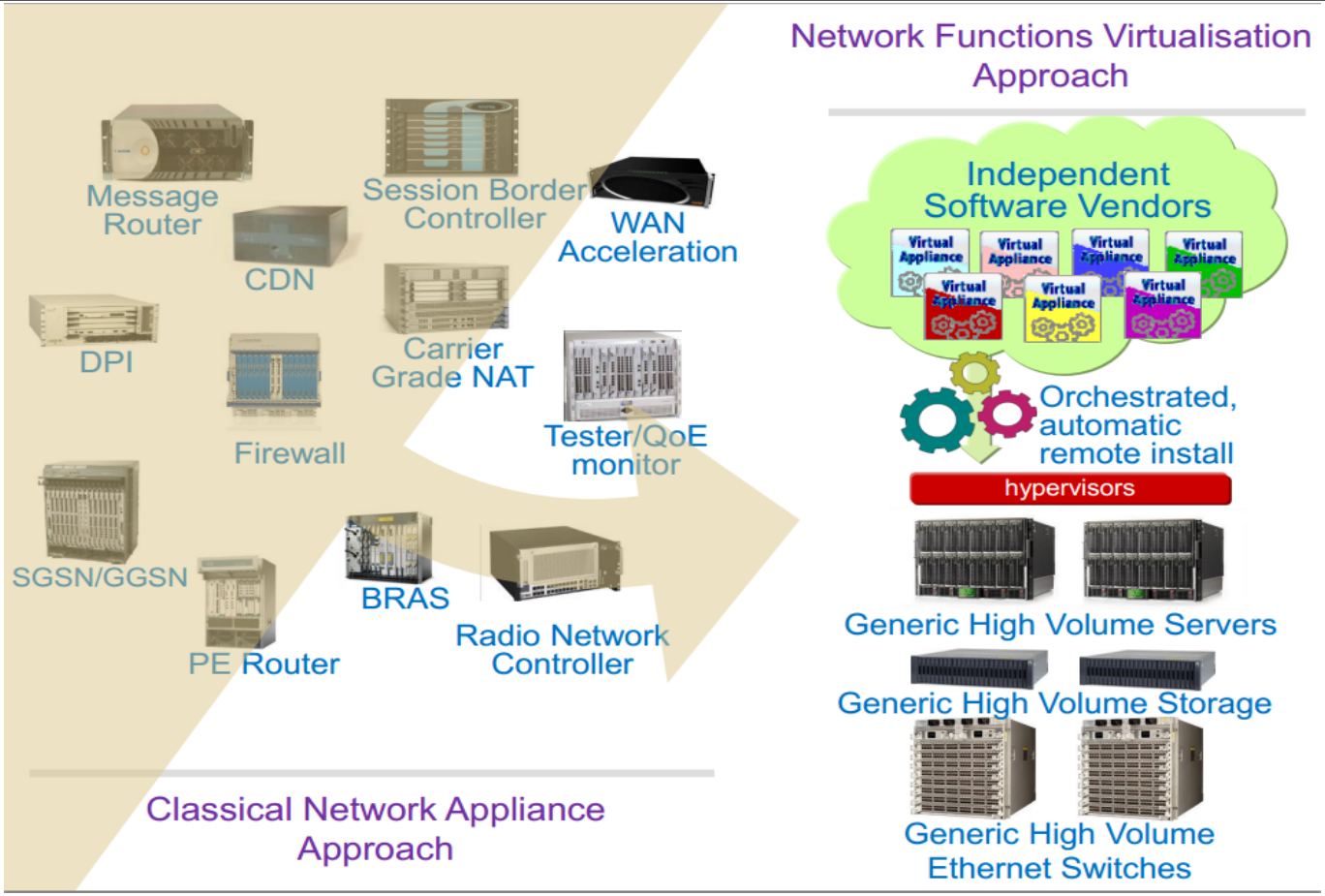
Examples

Independent Software vendors => an App market for Networks



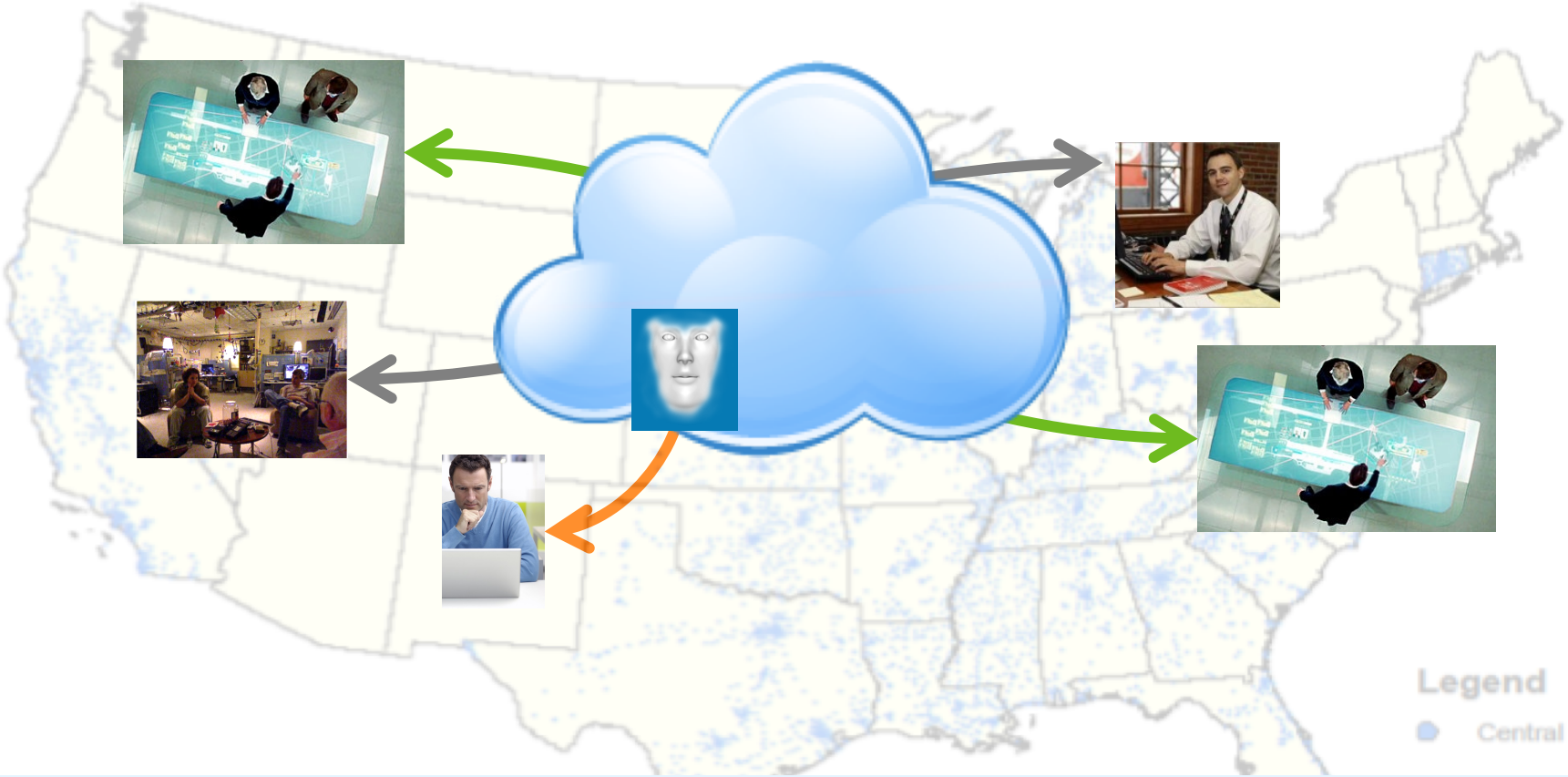
http://www.ietf.org/proceedings/86/slides/slides-86-sdnrg-1.pdf

Recent annual report from service provider: > 50% 'network functions' have been 'virtualized'

Mobile Edge Cloud: Motivation

Mobile devices: Portals to rich services (compute & storage) in cloud

Edge-Resident Cloud: puts cloud resources "into" devices, "at" locations



- Provides **enhanced responsiveness** on resource-constrained **thin client**

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EC Vision

Emerging Devices

Connected Car

Remote Work

Life: IoT

Ubiquitous

Responsive

Elastic, Secure

Speech Recognition

Location

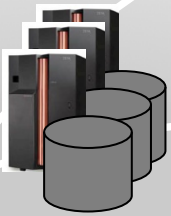
Translation

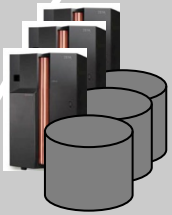
Gesture, Gaze, oice gnition

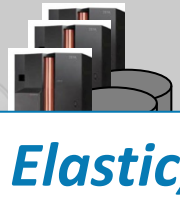
Presence Messaging

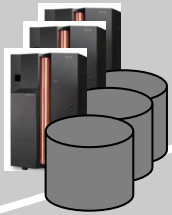
Biometrics

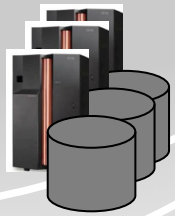
Image, Video Processing











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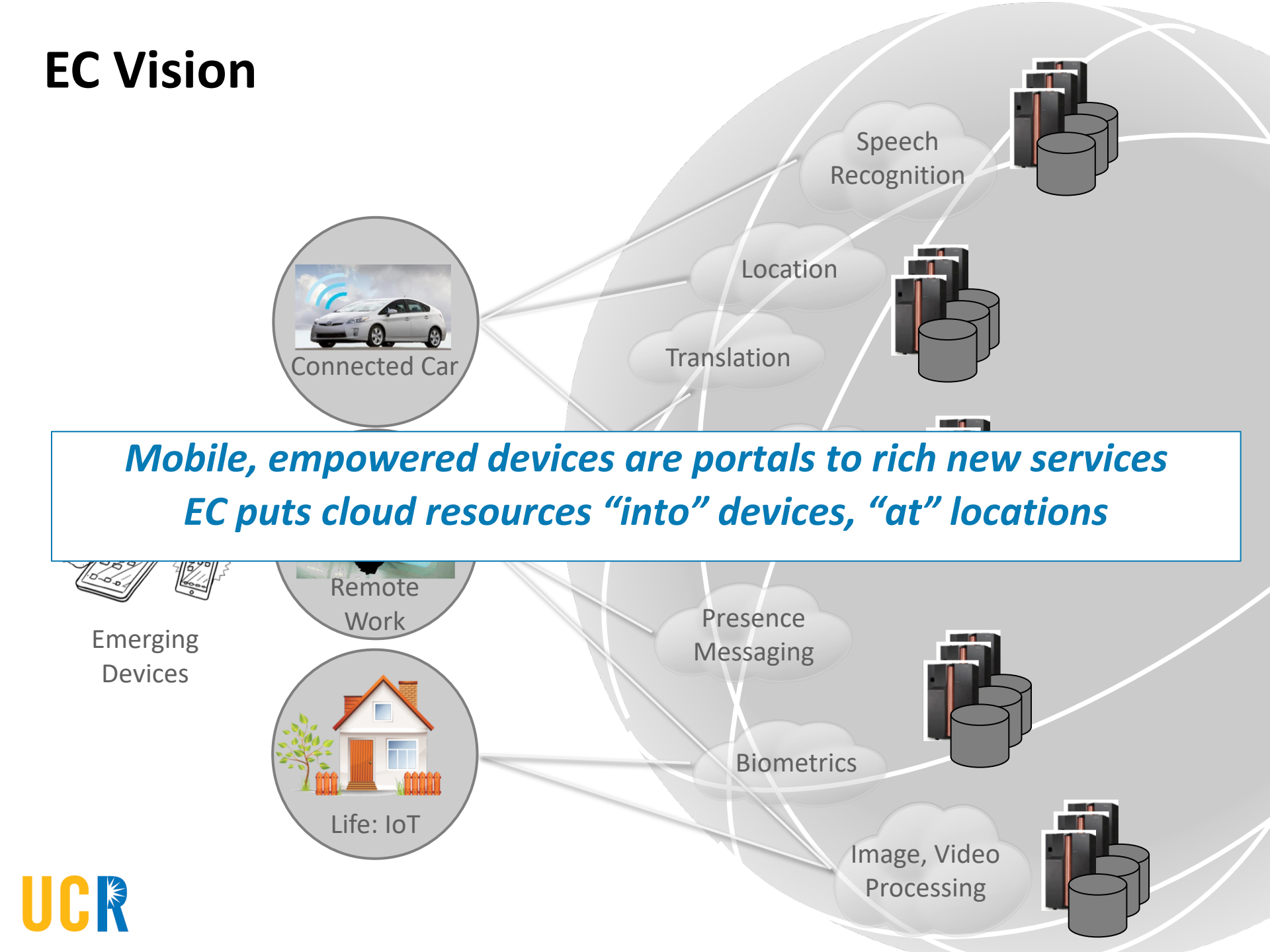
EC Vision


Speech Recognition
Location
Translation
Connected Car
Mobile, empowered devices are portals to rich new services
EC puts cloud resources “into” devices, “at” locations
Remote Work
Emerging Devices
Presence Messaging
Biometrics
Life: IoT
Image, Video Processing

Mobile Edge Cloud: Deployment Challenges, Incentives

- Applications can take advantage of edge cloud resources for
  - Improved latency; better responsiveness
  - Better quality of experience enabled by caching, customization
- But it **requires ubiquity of deployment**
  - When edge clouds available only at selected locations, but not others, result in highly variable QoE
- **Incentives** need to be compelling for infrastructure deployment
  - What is the revenue stream for the infrastructure owner?
  - Will users pay for improved latency/responsiveness?
  - How much time after infrastructure deployment for large-scale use?
- Applications have adapted to the Internet's variability
  - End-system buffering; Rate Adaptation; CDNs
- Helpful if infrastructure owner itself sees benefit
  - Ease demand for additional resources

    Protect and grow future businesses

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Motivating Example: Vehicular Safety

- Vehicular safety: use of sensors and technology is growing rapidly
- Considerable investment from automobile industry - a strong consumer of networking technology
  - Vehicles are communicating sensors/IoT devices on wheels
- Communication: A number of situations - critical safety information needs to be provided to right recipients in a timely manner – *timeliness*, *relevance* and *coverage* are key
  - Vehicular Safety is a key domain where such information dissemination can make the difference between life-or-death

- One example of such a vehicular safety application: black-ice warning
- Need to get right information (hazard of black-ice) at the right time to those vehicles that are going to be impacted, *but before they experience it!*
  - Critical real-time requirement
- Infrastructure assistance can be very beneficial for timely dissemination
- Information Centric Networks can be very helpful in this context: but needs help from the 'edge' computing capabilities

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Black Ice!

- **Black Ice**: A glaze that forms on surfaces (especially roads, sidewalks, and driveways) because of a light freezing rain or because of melting and re-freezing of snow, water, or ice, on surfaces
  - Can't be seen
  - Vehicles can't be controlled
  - Too late to depend on local sensor
  - Local law enforcement generally react after the fact

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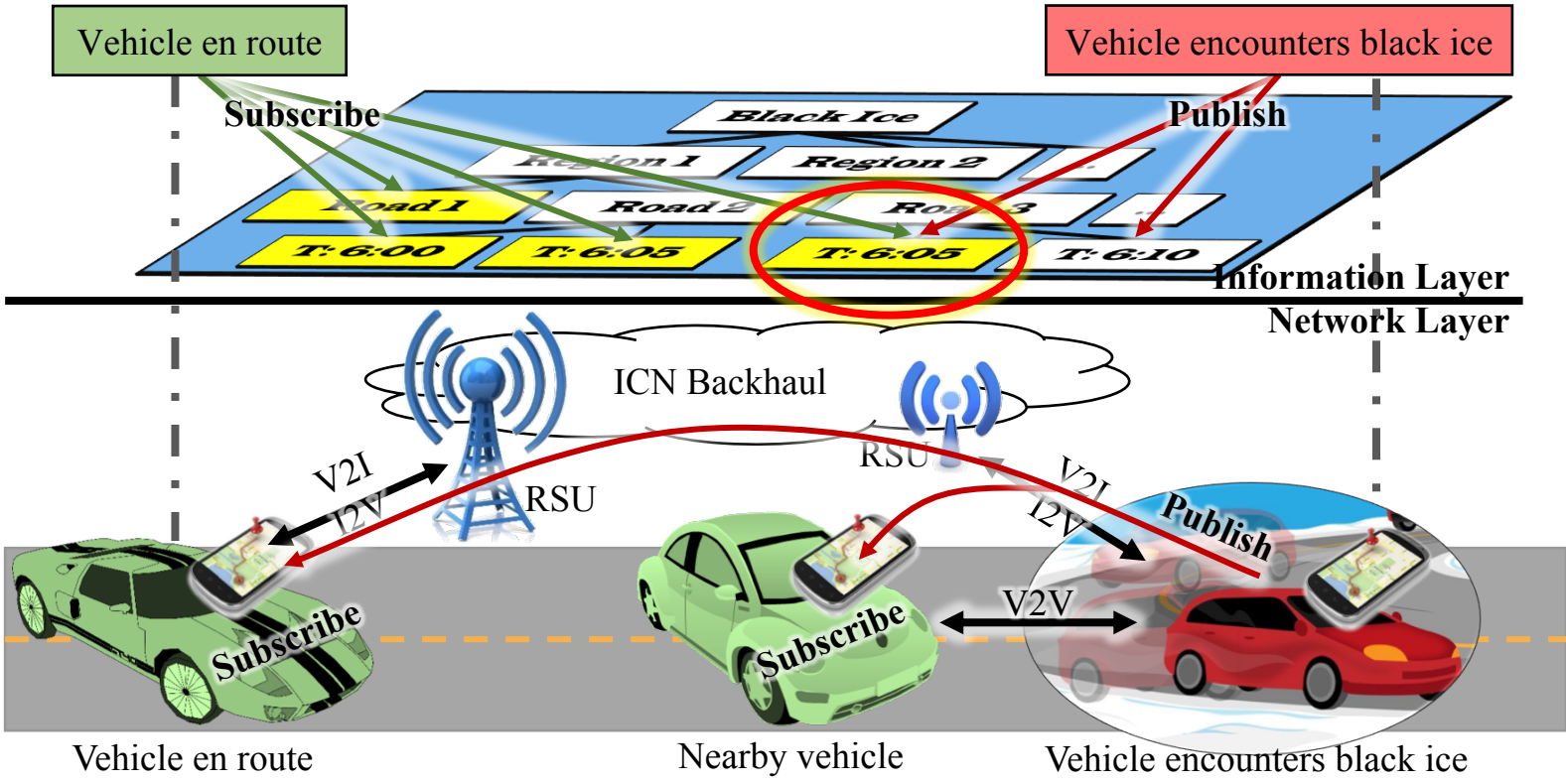
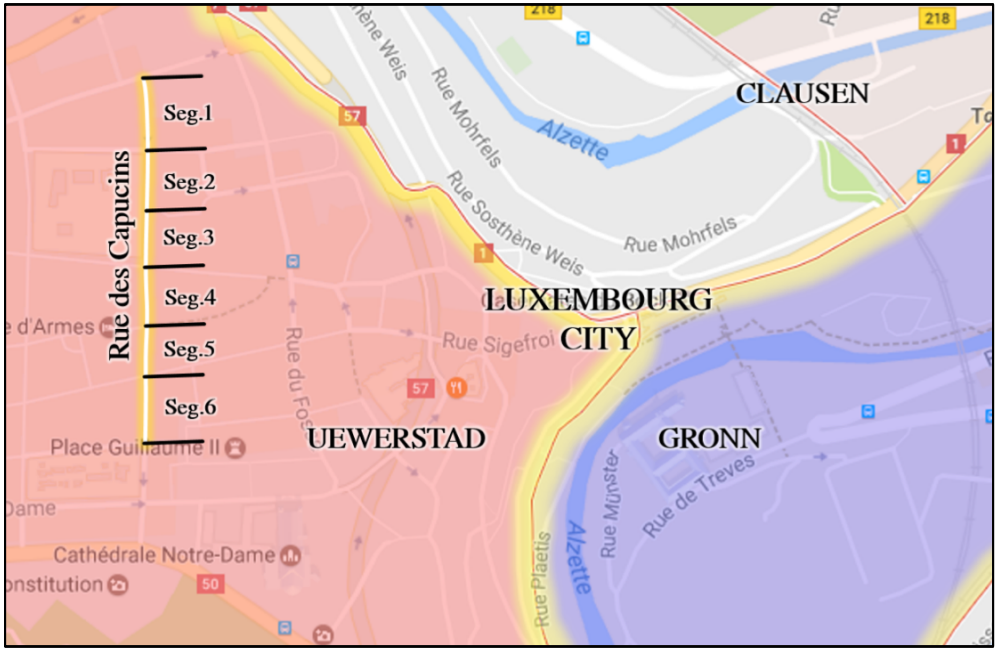
V-ICE Overview

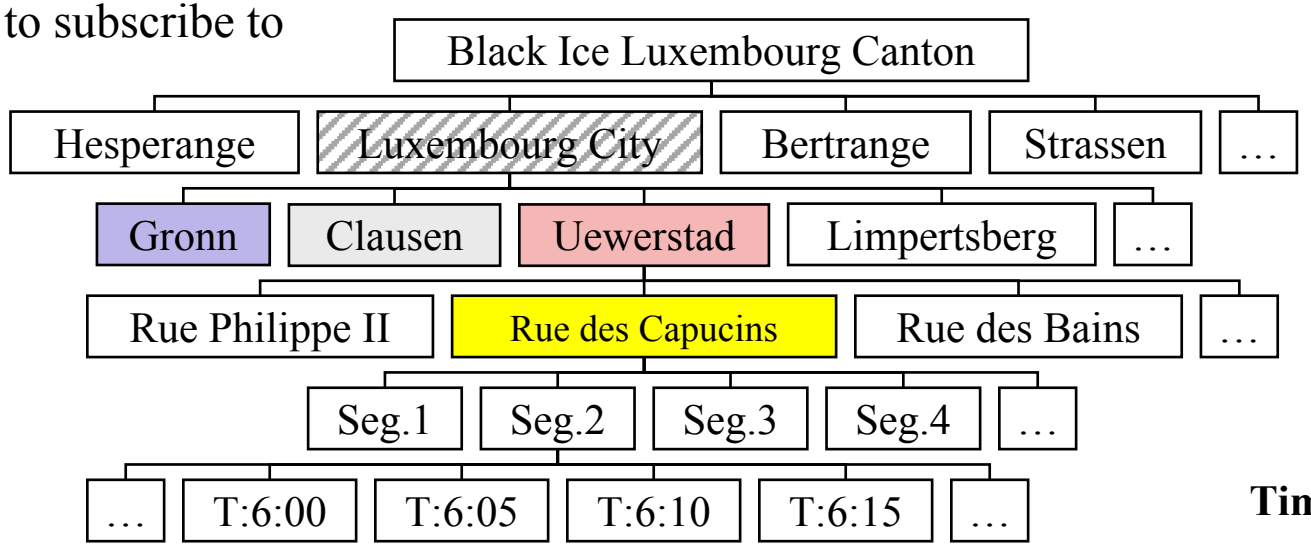
- V2I & V2V communication for safety information dissemination
  - Vehicles transmit notifications (location, time & duration) to the nearest RSU
  - RSUs connected through a (multi-provider) backbone network
  - Notifications delivered to vehicles interested in (will drive on) location at given time
- A namespace that enables identification of the geographical location and time



Naming Schema

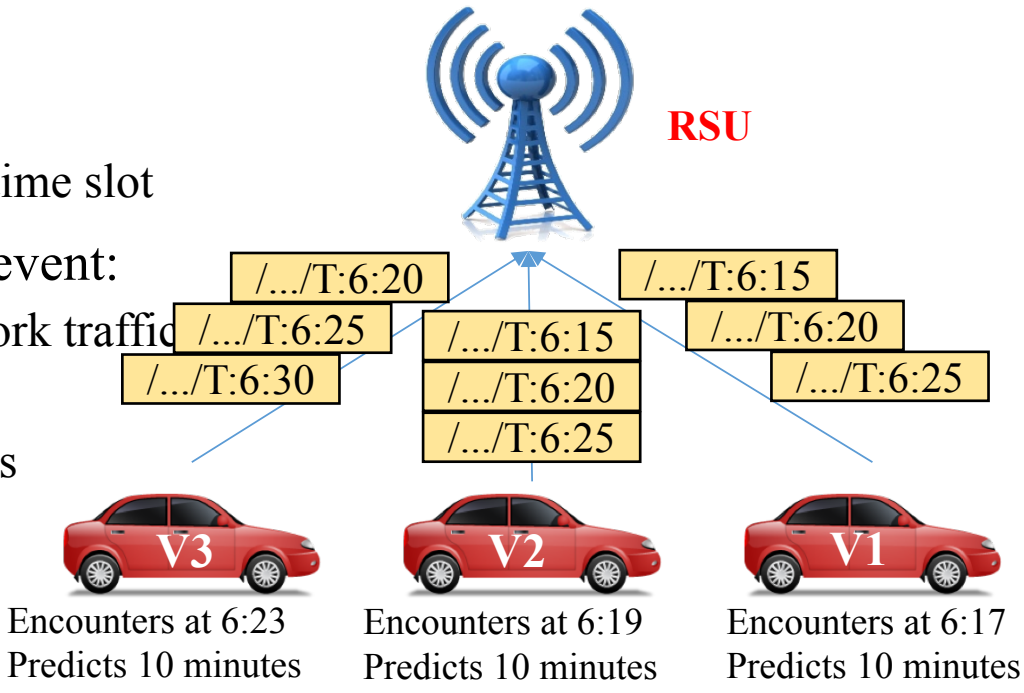
- Assists drivers to precisely determine
  - Where black ice occurs
  - At what time & for how long
- Supports aggregated subscriptions
- Hierarchical name space
  - Event: /blackIce/*location*/*T:<time>*
  - Location: hierarchically structured (e.g., region, road, segment, …)
  - Time: time slots (e.g., 5min)
- Vehicle route planning & rerouting
  - Determines what to subscribe to





Message Publication & Filtering

- Message Publishing
  - Name: /blackIce/*location*/*T:<time>*
  - One message applicable for whole time slot
- Many vehicles may report the same event:
  - Costly in terms of energy and network traffic
  - Distracting to drivers
  - Need to suppress duplicate warnings
- In-network message filtering
  - Messages filtered at RSUs, based on names



Time		6:15—6:20	6:20—6:25	6:25—6:30	6:30—6:35
V1	Predict				
	Message	Sent	Sent	Sent	
V2	Predict				
	Message	Filtered	Filtered	Filtered	
V3	Predict				
	Message		Filtered	Filtered	Sent

Reliable Pub/Sub (V-ICE-R)

- Important to deal with occasional vehicle-RSU disconnections; and new vehicles joining a road segment
  - Drivers miss critical warnings when disconnected from RSUs and during hand-over

- Use store-and-forward capability (e.g., MobilityFirst)
  - RSUs buffer all warning messages
  - Newly arriving/re-connecting vehicles receive past, but relevant, notifications
- Edge Resources at the RSUs are key to be able to store-and-forward and perform the appropriate filtering

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ICN and Edge Clouds for Vehicular Safety

- Vehicular Safety: Right information at the right time can reduce chances of accidents
- V-ICE: an information-centric pub/sub-based information dissemination architecture for vehicular safety warning propagation
  - Black ice as an example test case
- Infrastructure is a key component to managing information delivery
- Reliability measures (VICE-R) help in case of disconnections

- Combination of ICN and Edge Cloud platforms:
  - More efficient than broadcast flooding and server-based polling, in terms of timeliness and relevance

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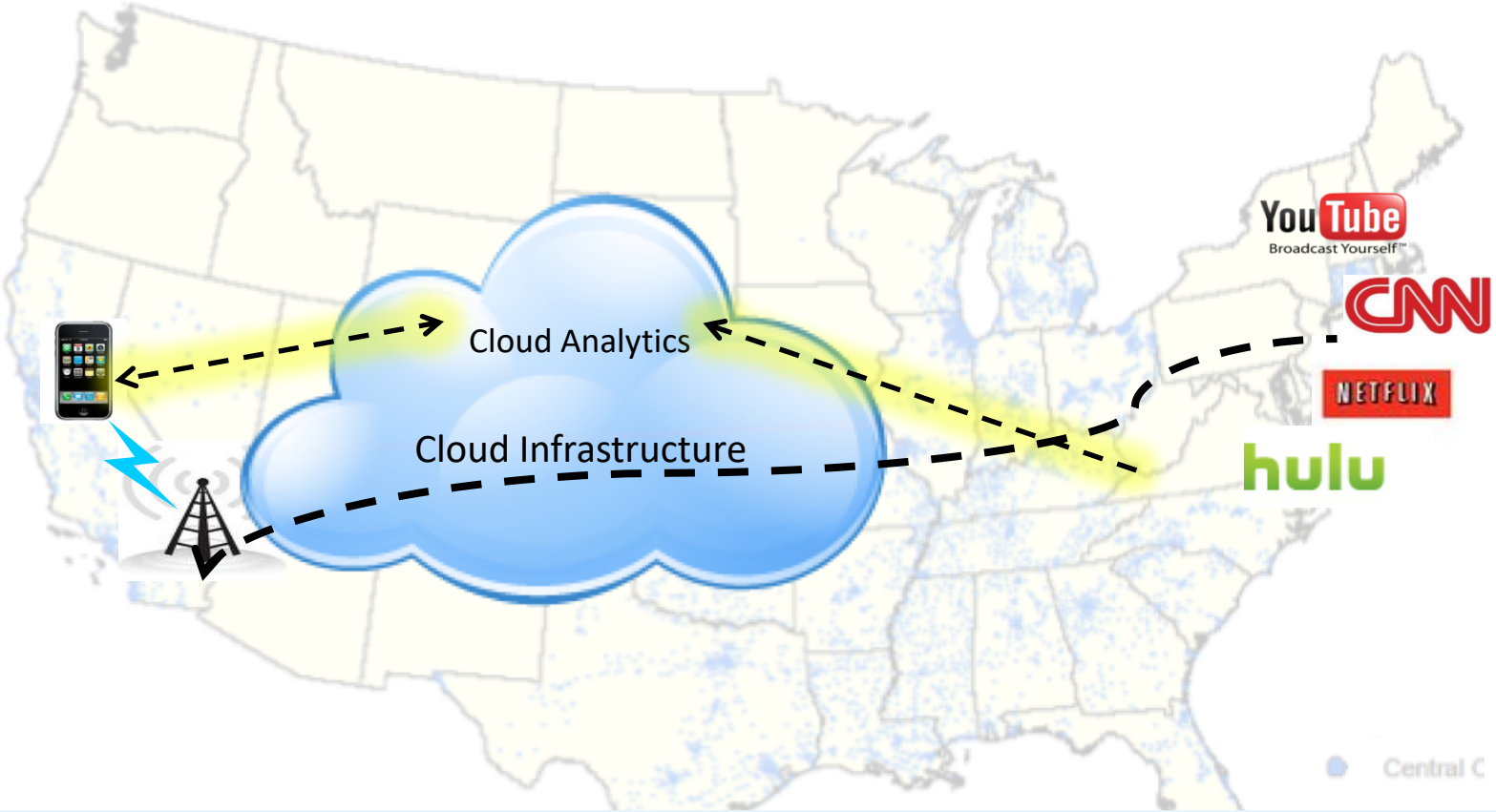
Motivating Example: Mobile Video Delivery

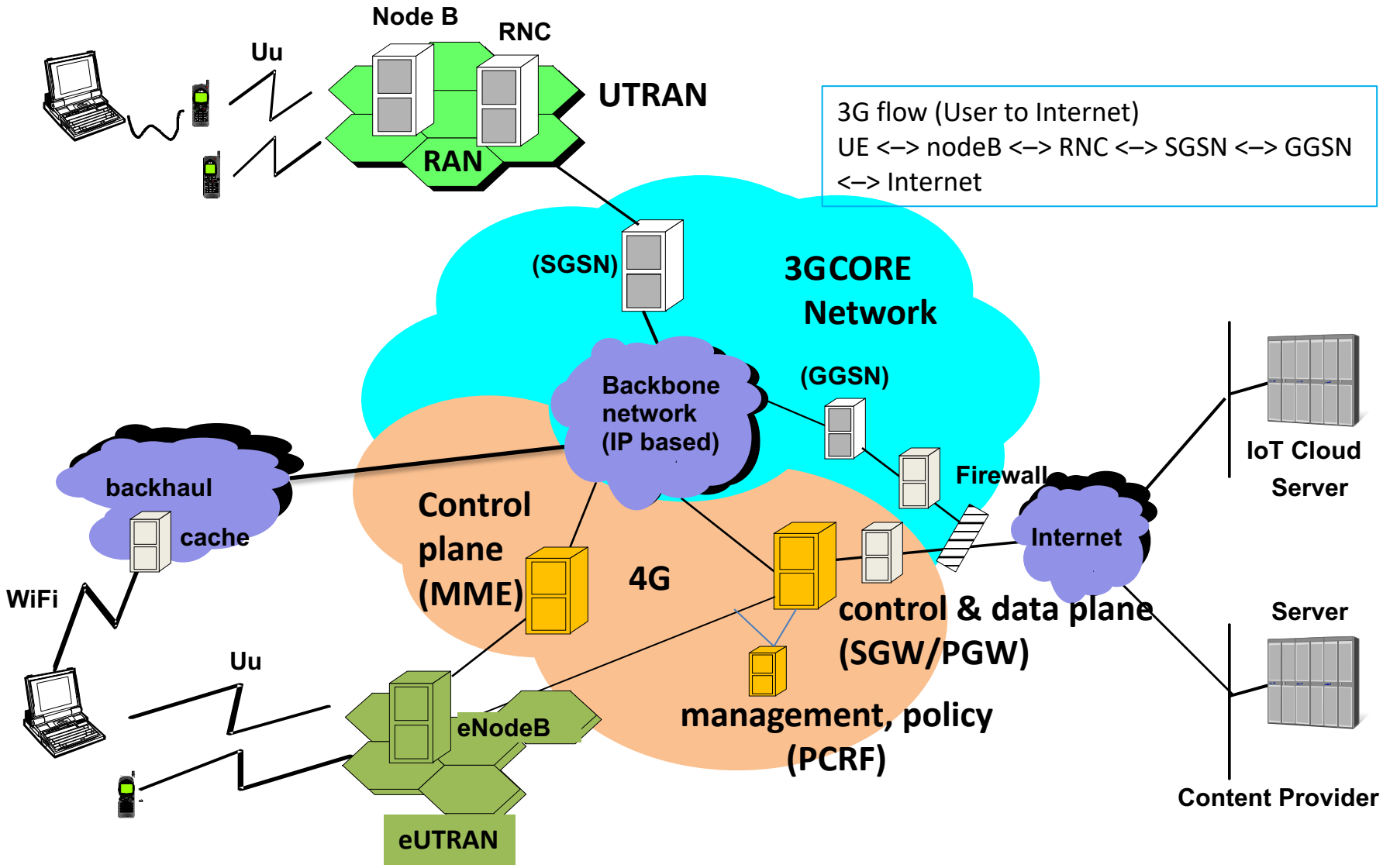
Incentivize Cellular Operator: Manage their resources better for existing services?



Optimizing delivery of mobile content

- **Cloud analytics** for improved discovery, recommendation, and personalization of content; pre-placement of content on end-devices
- **Cooperation** between the end-device, the RAN, and cloud resources to optimize delivery of personalized content

Cellular Network Architecture (3G & LTE)



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Living with the last hop bottleneck

- Cellular Networks: Radio Access Network (RAN) is usually the bottleneck
  - With backhaul going to Ethernet/fiber – backhaul not limiting factor usually
- Many of the traditional approaches to optimize content delivery are not as helpful
- Content Distribution Networks/Multicast have traditionally been considered for optimizing content delivery
  - Relieving the load on the backbone is helpful
  - but doesn't help reduce RAN utilization
- Latency on the RAN dominates
- Delivery over the RAN is primarily unicast

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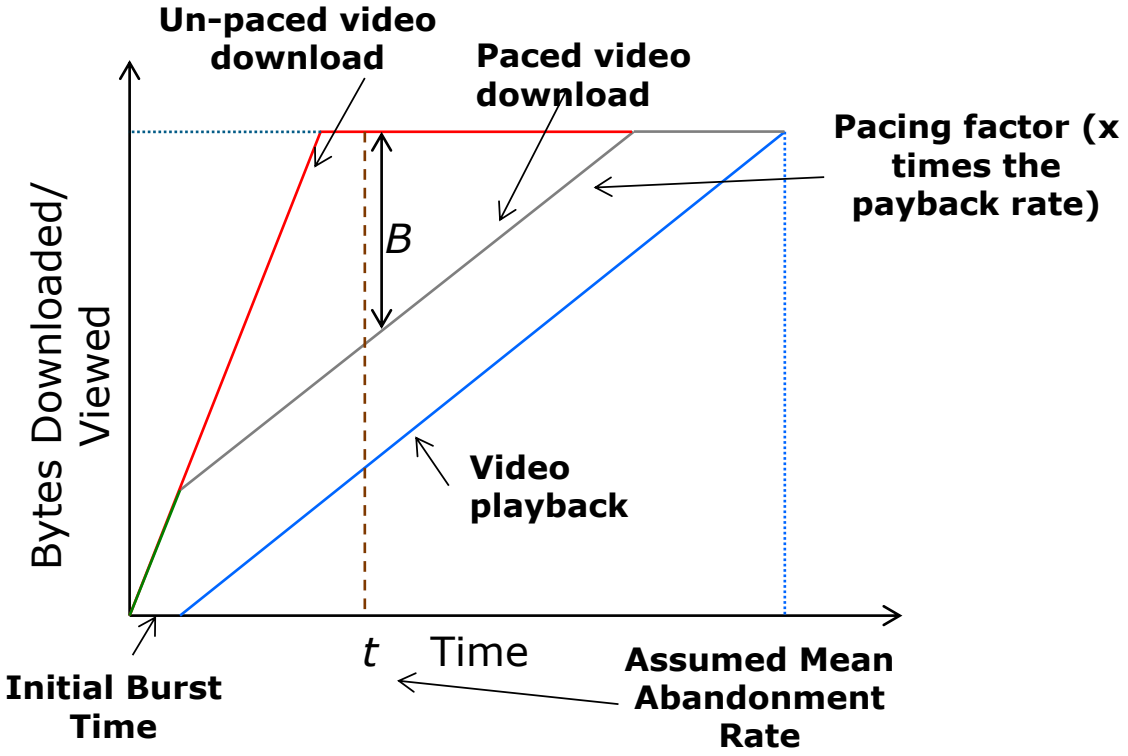
Relieving the Last Hop Bottleneck: Video Pacing



Bandwidth savings from progressive download pacing is realized by limiting the amount of content that is lost in the player's buffer when an end user **abandons** watching the video

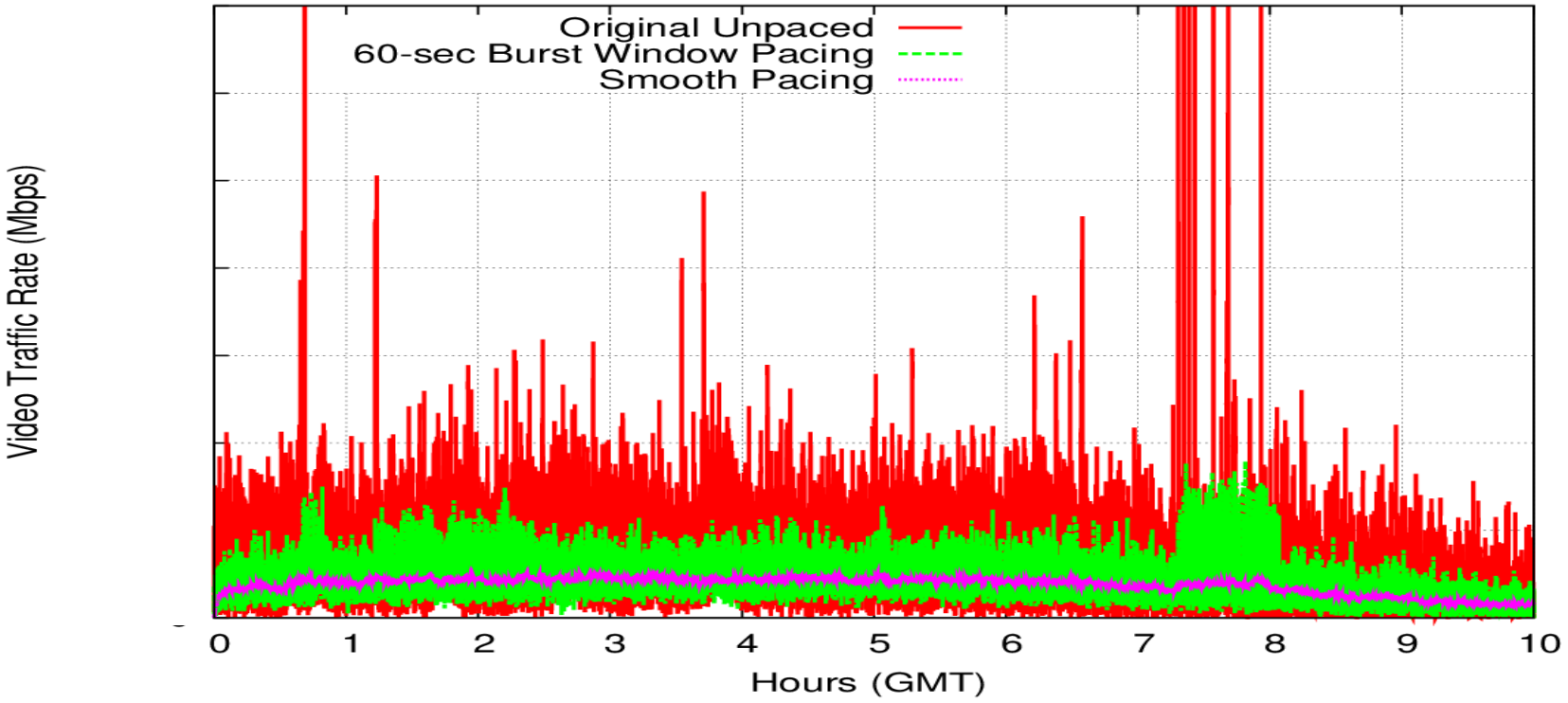
- If user abandons watching video at time *t*, the unused bytes *B* are saved from being downloaded

•Smoothing has a further benefit: reduce peaks in traffic

- •Provisioning of cellular network often based on peaks

Optimizing Mobile Video Delivery-Pacing

- Reduction of small % in overall volume of traffic; but peaks significantly reduced
- Pacing has multiplexing advantages
  - smoother flows -> better utilization



- RAN Awareness in Pacing: balance both mux. gain and proper radio resource management
  - Benefit –reduction in total RAN B/W usage; maintain user experience

Edge Cloud Infrastructure Requirements

- Each of these examples need an edge cloud infrastructure that
  - Achieves high performance
    - High Throughput
    - Low Latency
  - Can scale up to support a large number of users/flows
- The edge ‘cloud’ cannot be a collection of purpose/application-specific resources or hardware appliances
  - Infrastructure has to inevitably adapt to changing needs
    - Support new applications
  - Allow for multiplexing of resources across applications
- Software-based environments that achieve high performance are becoming feasible
  - Virtualization allows for multiplexing

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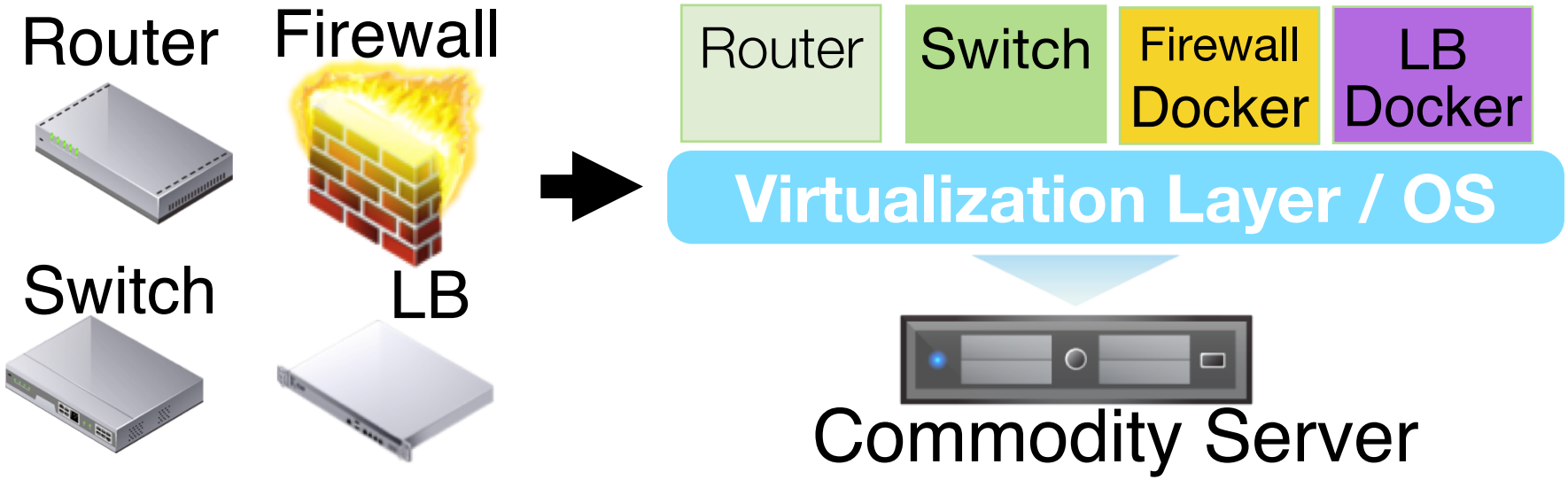
Network Function Virtualization

. Run network functions in software



. More flexible than hardware

- Easy to instantiate new NFs
- Easy to deploy NFs; Easier to manage NFs

- Network Service Providers are migrating towards a software based networking infrastructure (55% by one recent estimate)

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NFV Application Opportunities

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- NFV creates opportunities for us to re-think how network infrastructure is designed and deployed
- Creates flexibility – evolving the network and adding new functionality can be quicker
  - Testing, Verification of Software – not a completely new platform
- Scalability – instantiate new NF instances
  - Dynamically add instances of a particular service type
- Application scenario: Cellular network infrastructure
- Cellular EPC involves multiple components in both control and data plane

Cellular EPC: Distributed Hardware

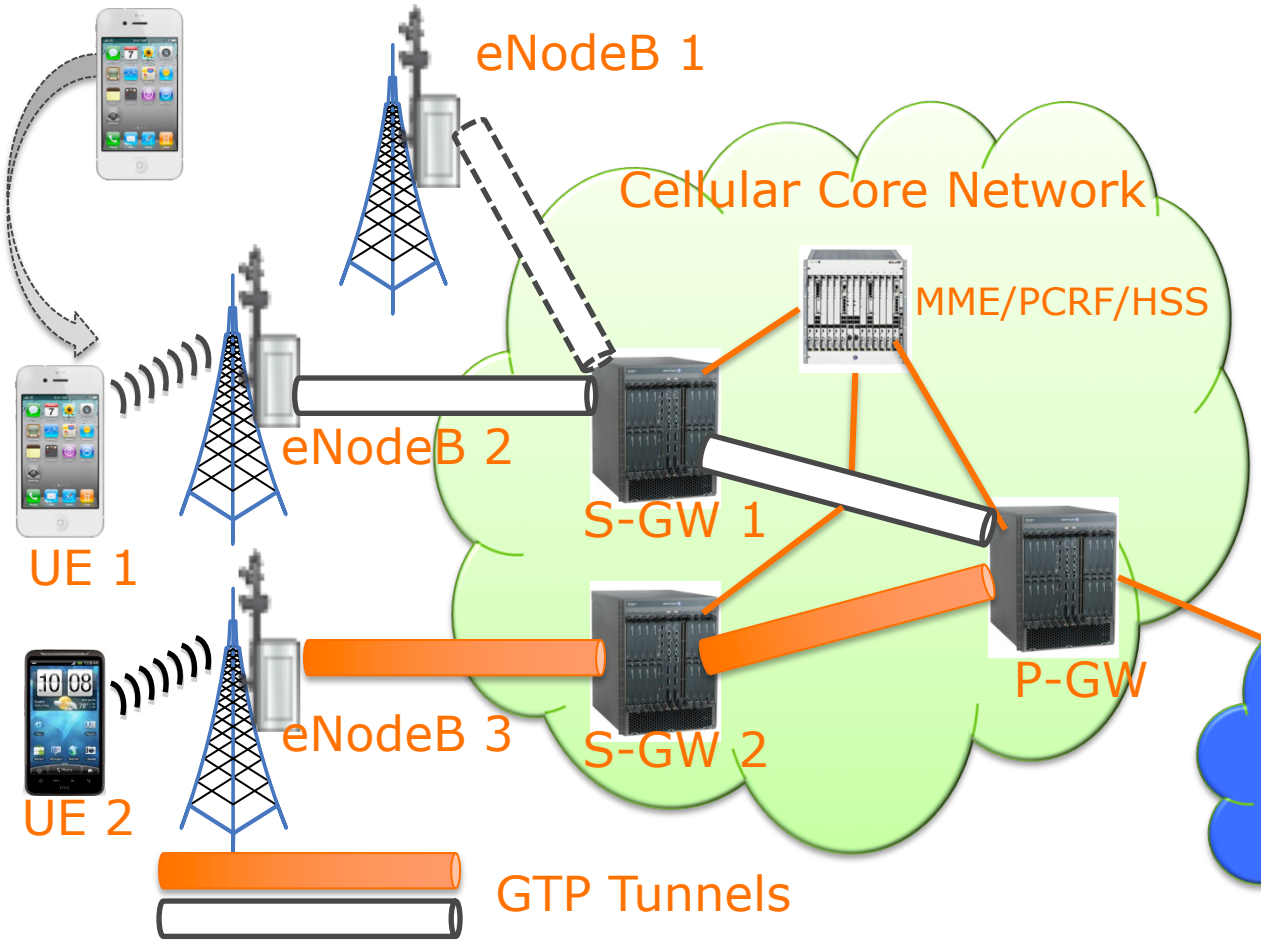
- Cellular network EPC: Separate purpose-built hardware appliances for each function
  - A number of distinct components
  - Architecture: evolved from traditional circuit/virtual circuit-switched network design
- Separate data plane and control plane components
  - Need to keep state consistent across all components
- Complex protocol; many messages

Need: Scale; Efficiency

- Shift to smaller cells to increase system capacity
  - More frequent control plane exchanges (handovers)
- New uses of cellular networks: Internet of Things (IoT)/Machine to Machine (M2M)
  - Increased control plane load from low power devices that switch between idle and active states frequently
  - Different communication patterns – small packets, infrequent communication
- Needs efficient, scalable control plane - to be viable for users and operators

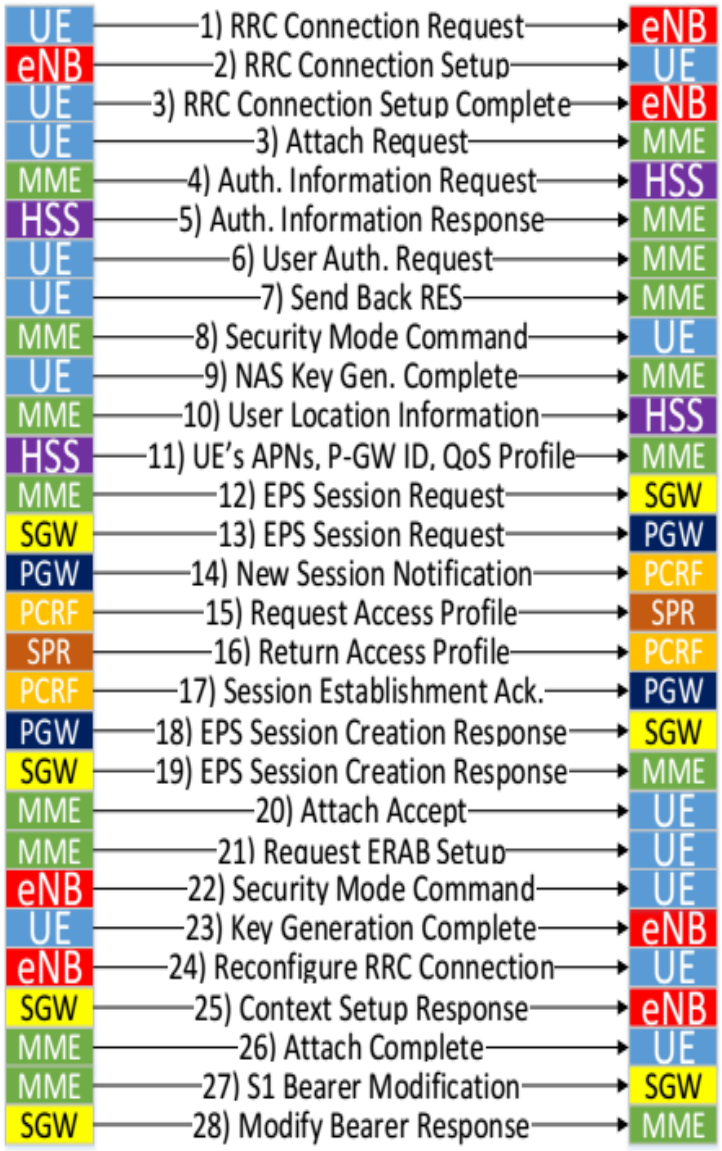
LTE Infrastructure: use of GTP Tunnels

Communication between the mobile device and IP network is over tunnels

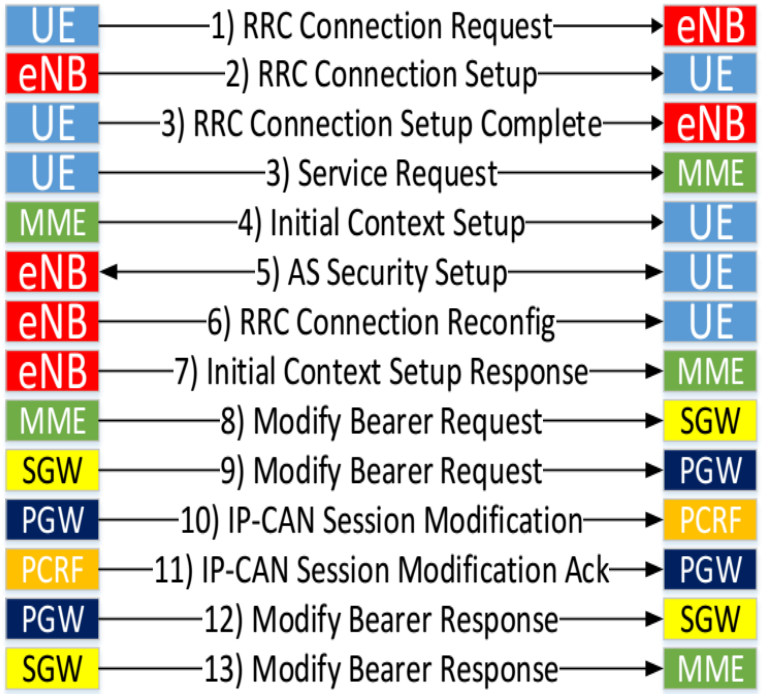


- UE: user equipment
- eNodeB: base station
- S-GW: serving gateway
- P-GW: packet data network gateway
- MME: mobility management entity
- HSS: home subscriber server
- PCRF: policy charging and rule function

Messages Exchanges in Traditional 3GPP Approach



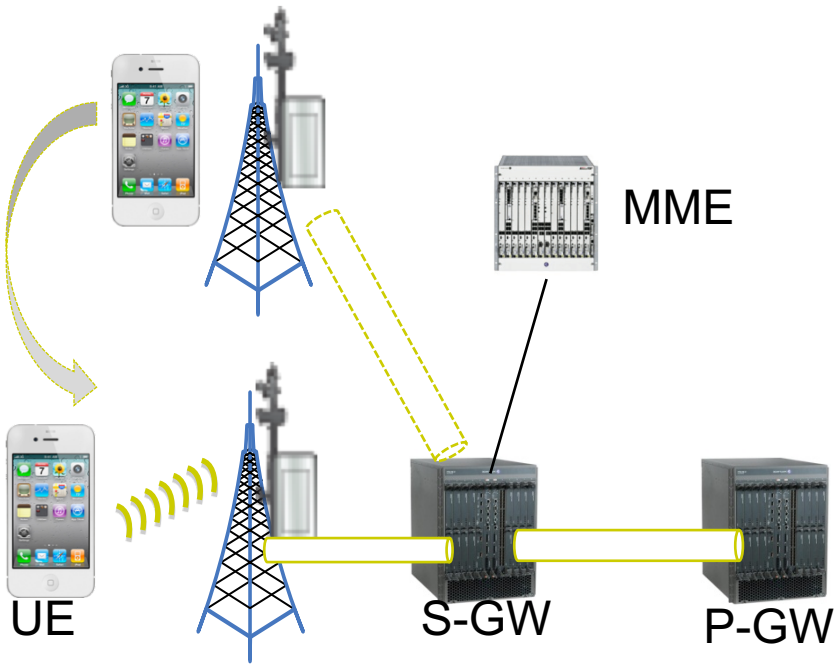
Initial Attach



Service Request
(Idle to Active)

Mobility Management

- Handoff without change of S-P GW – (S1 handoff)
- Results in up to **29-33 control messages** in total, across S-GW, MME and eNBs.
- Handoff with change of S-GW or MME has more overhead
- Mobility of a large # of IoT devices – overhead will be of concern



Opportunity: NFV-based Arch. & Protocol

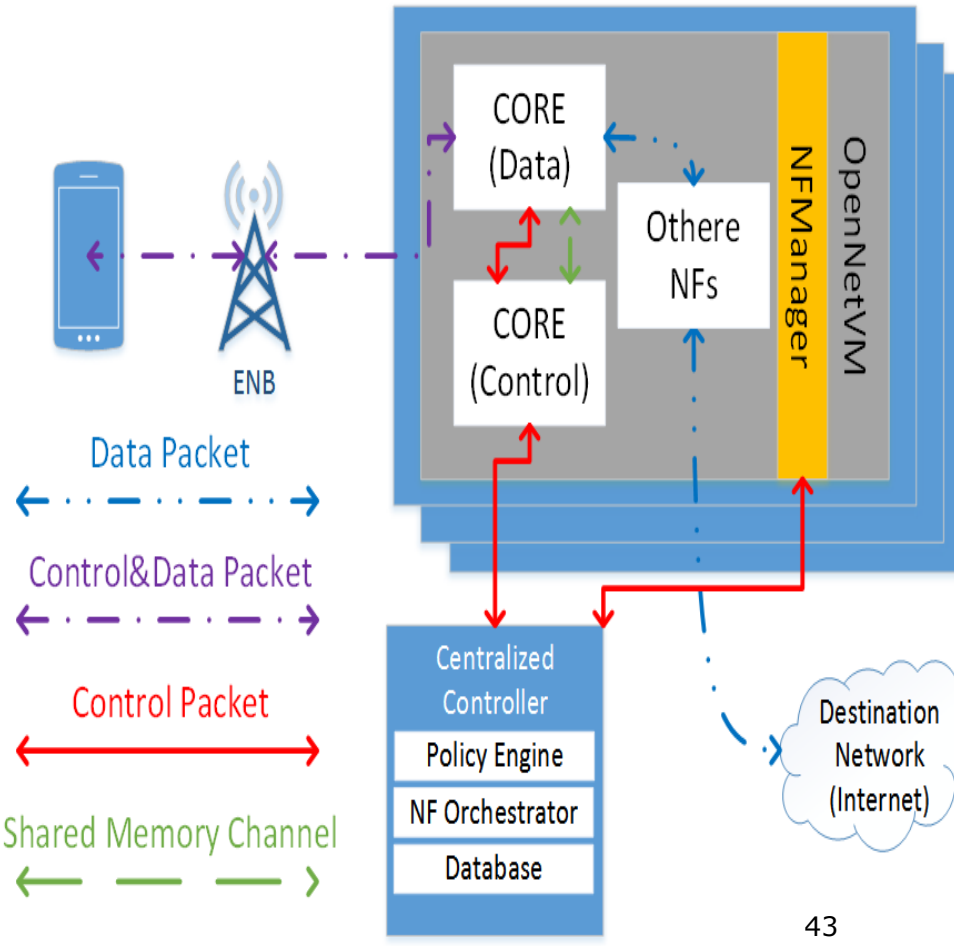
- Tight coupling between data and control plane in cellular networks
  - Dis-aggregation- need to lower latency for control plane transactions to take effect: extra delay between data/control plane
  - All control state for a session in separate entity, distinct from the data plane
  - Separating this state comes at a price!
- Re-think the control plane protocol to leverage the opportunities of new architecture

Rethinking the Design for Cellular EPC

- CleanG Protocol:
  - Reduce the number of control plane transactions
    - Simplify the control plane protocol
- CleanG Architecture: A more scalable architecture
  - Consolidation of EPC components
  - NFV based: scale-out to meet demand for data plane and control plane
- Optimize protocol & architecture for common case
  - Lower overhead for the common cases
- Take advantage of SDN where appropriate
  - Use SDN-design for higher level policy enforcement

CleanG architecture

- Have a single system implementing EPC
  - ‘CORE’ Data and Control
- Run on NFV platforms
  - Like OpenNetVM
- Minimize delay between data and control plane
  - Leverage shared memory
- Dynamic resource alloc.
  - Control/data plane resources can be scaled separately



Leveraging IP: Eliminate GTP Tunnels; use DSCP

Using GRE tunnels instead of GTP tunnels

Avoid exchanging extra messages to setup dedicated tunnels - use DSCP

Example: DL, default bearer

EnB_DL_Table0

Lookup (IP, DSCP)	Data	Action
UE_IP, 0	Radio_ bearer_ default, QCI	Decap, Send_out(to _radio_bear er_default)

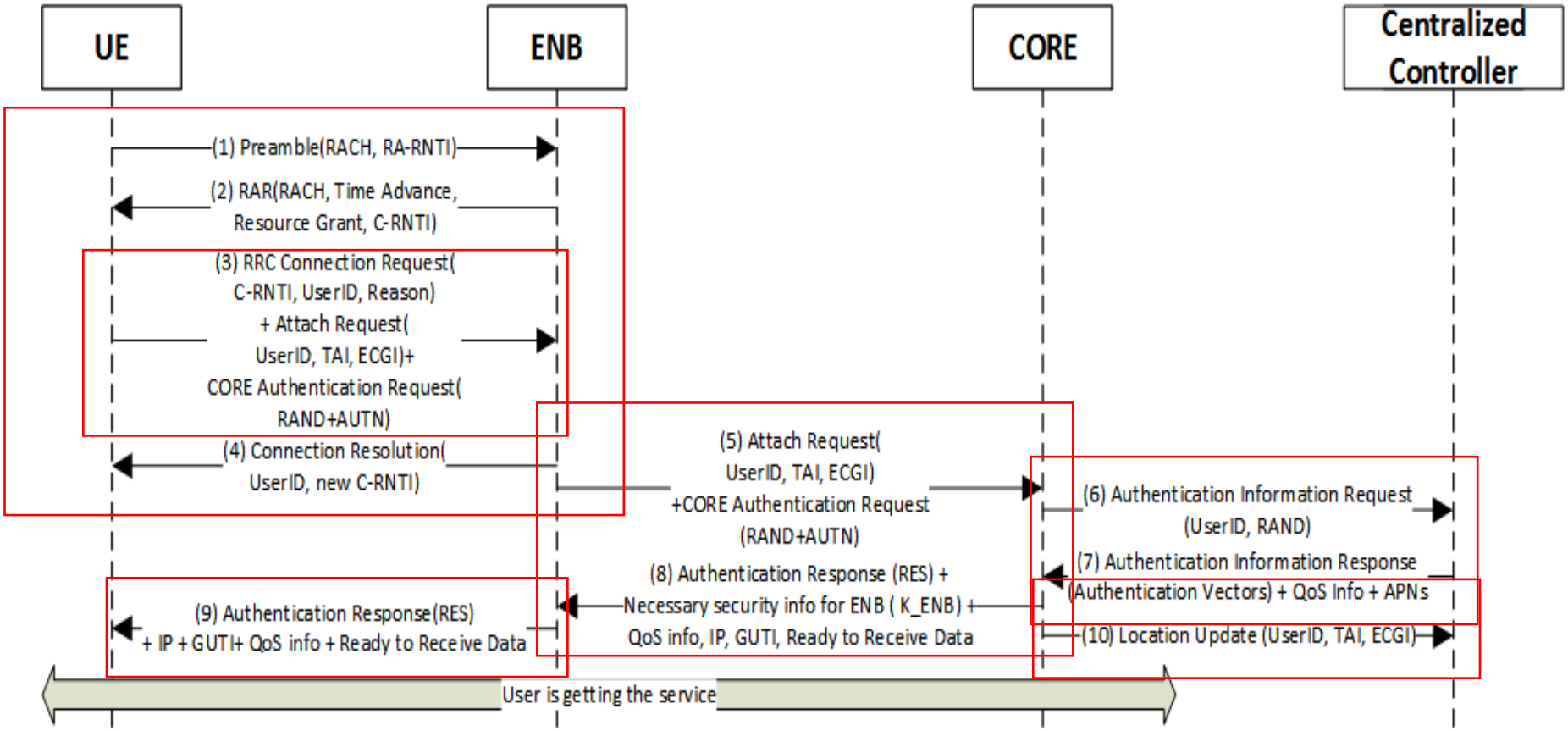
Core_DL_Table0

Lookup (IP, [QoS Filters])	Data	Action
UE_IP	ENB_IP DSCP=0, QCI	Encap(IP=EN B_IP, DSCP=0) Send_out()

Packet goes to UE

Packet from application server to Core

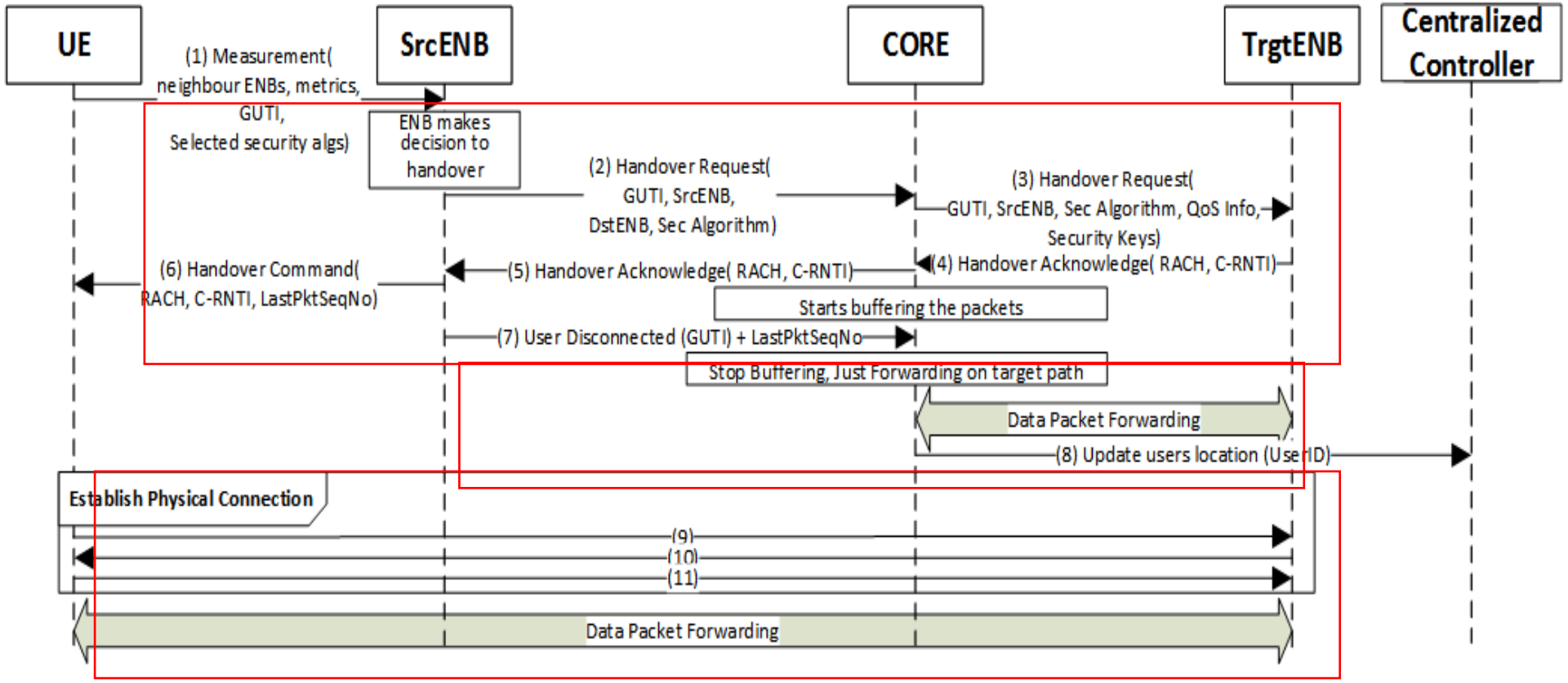
CleanG protocol - Attach



Compare to the 30 messages in current protocol

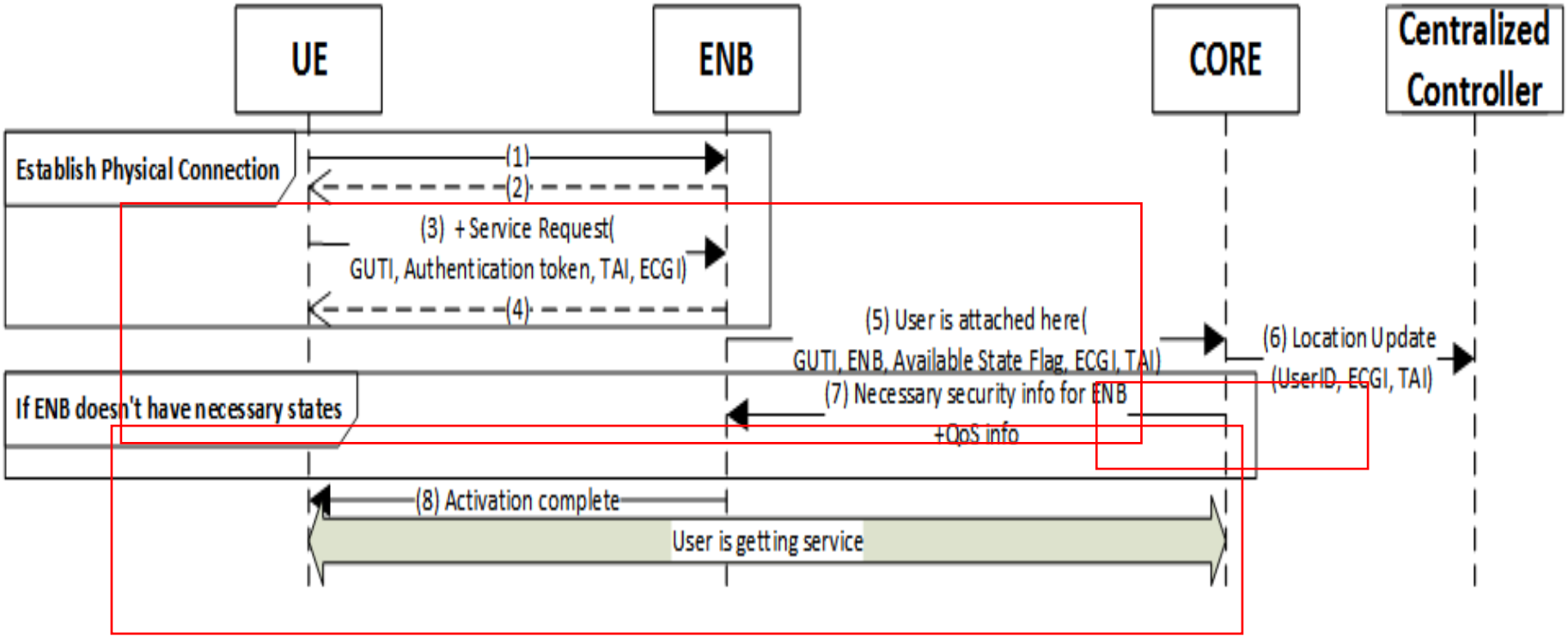
CleanG protocol – Handover

- S1 handover – Delay Tolerant Traffic



Compare to about 25 messages in current protocol

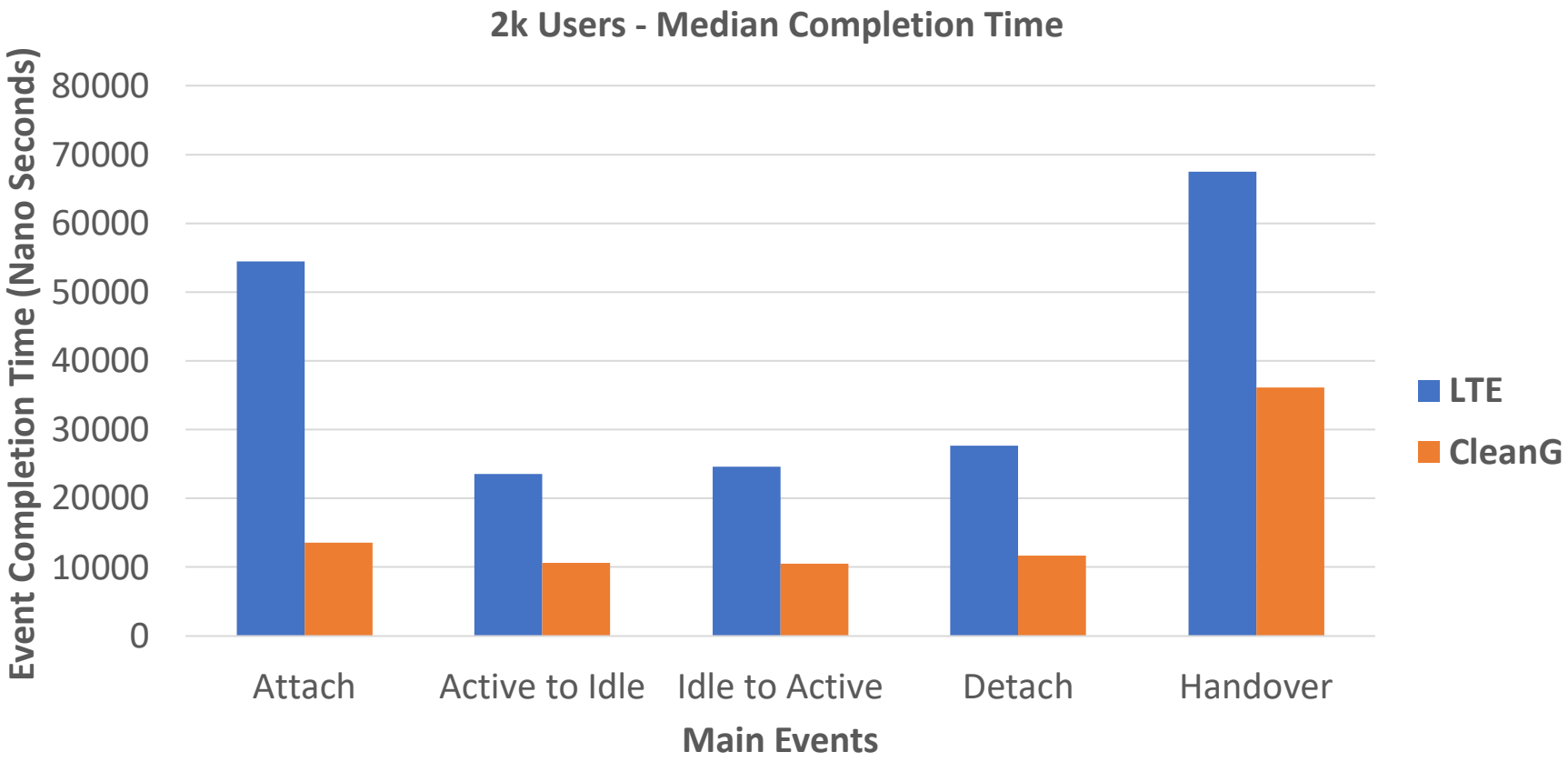
CleanG protocol – Idle to Active



Compare with about 15 messages in current protocol

Performance with CleanG

Representative Workload of users attaching to network, transitioning between active/idle, handovers



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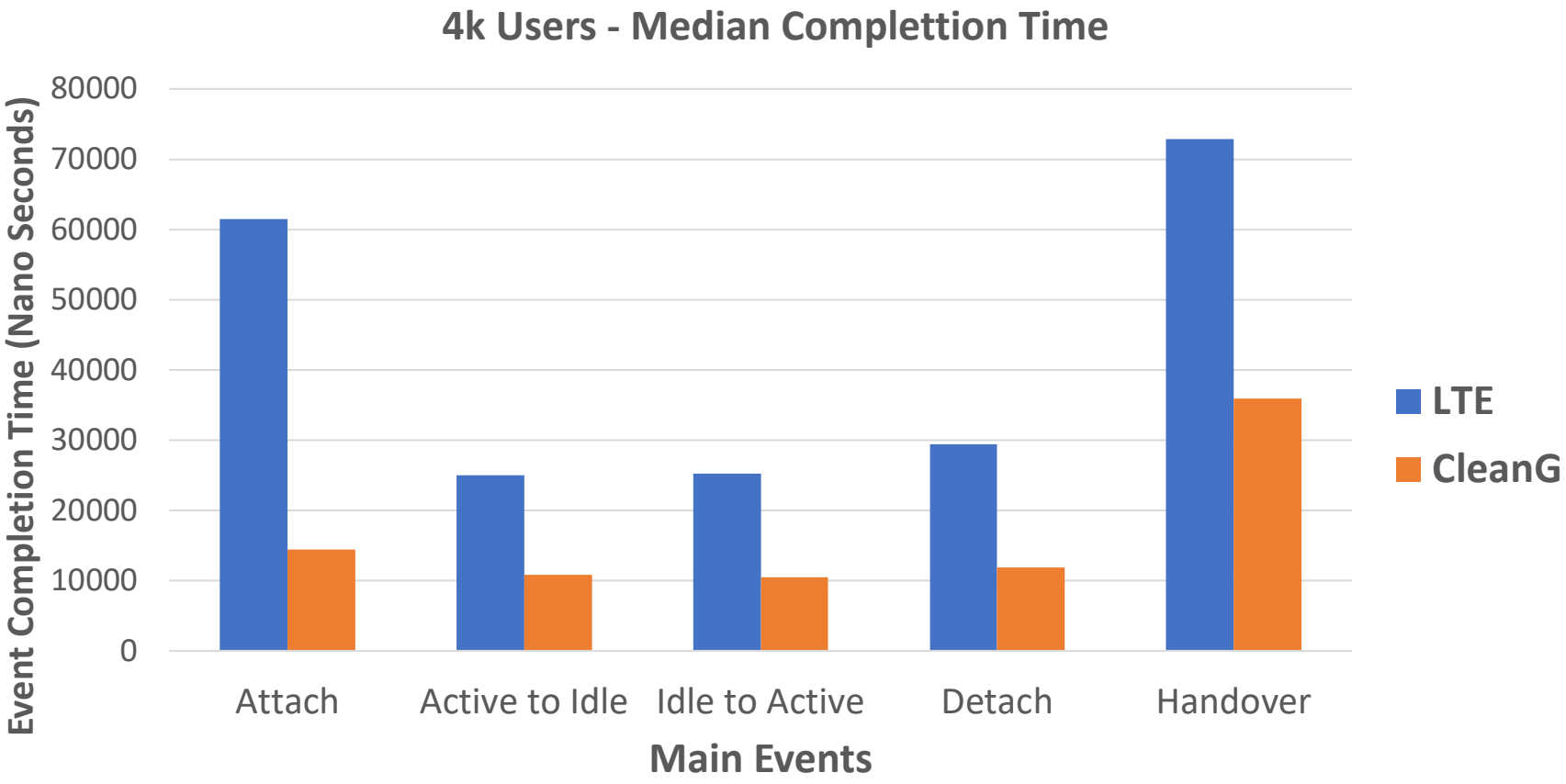

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Getting OpenNetVM

- Source code and NSF CloudLab images at

  http://sdnfv.github.io/

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