Emerging Networks: Edge

CS204: Advanced Computer Networks

Nov 22, 2023

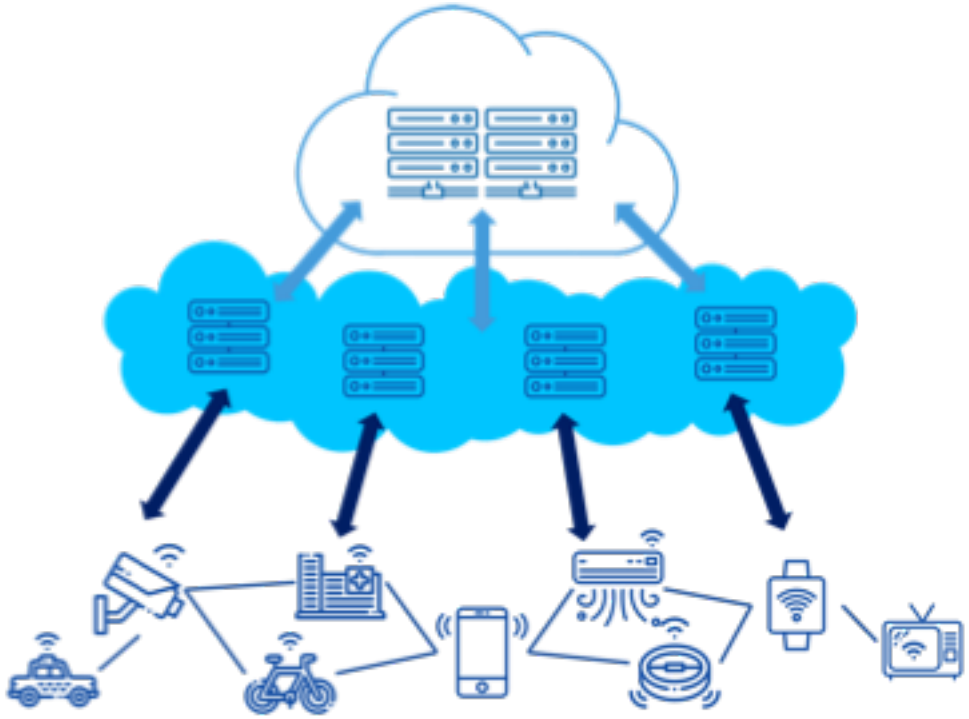
Agenda

- Introduction to edge computing
- Common techniques used in edge
- Mobile Edge

Edge Computing

- Idea is to push applications, data and computing power to the edge of the Internet, in close proximity to mobile devices, sensors, and end users

- An early example is Akamai, with servers around the world to distribute web site content from locations close to the user (content delivery networks, or CDNs)



Edge Computing: Key drivers

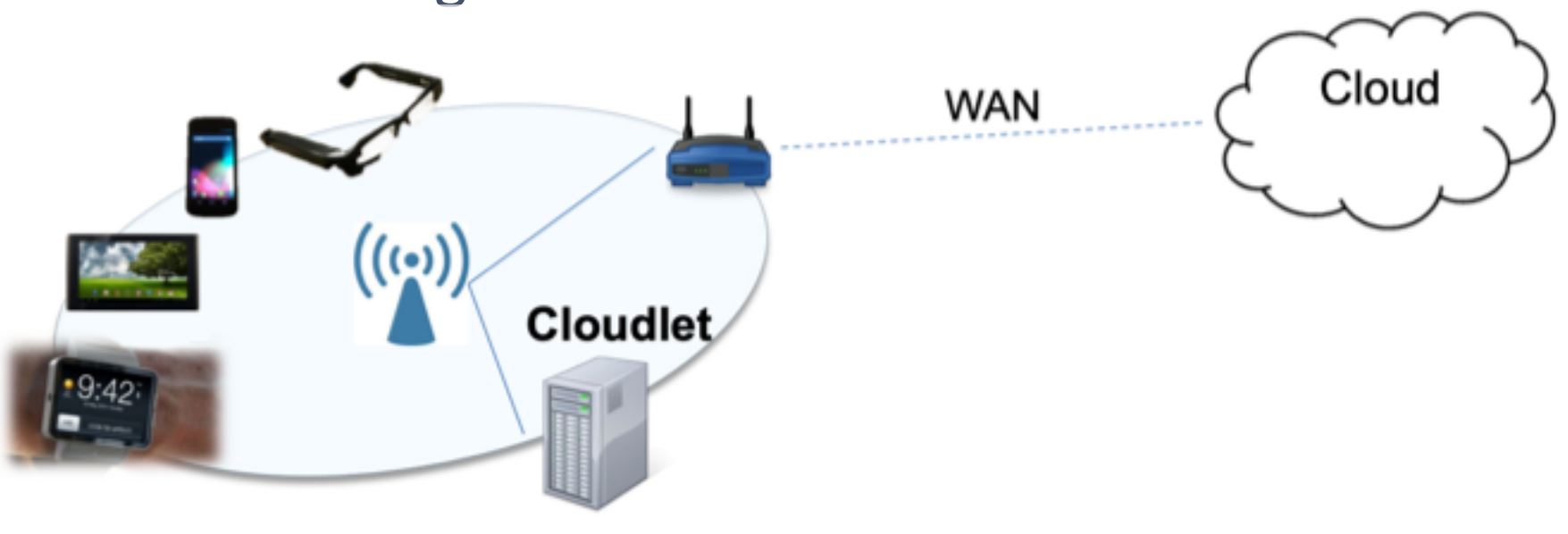
- Latency
  - data processing close to where it originates to avoid round-trip time
- Bandwidth
  - optimization of communication to and from the cloud
- Privacy/security
  - sensitive data stays local (New concept: Federated learning)
- Connectivity
  - continued processing (in some cases) despite lack of connectivity to the cloud
- Local dependencies
  - data processing close to points of interaction with end users and other system components

Evolution of Edge Computing

- Cloud computing [2000]
- Cloudlets [CMU 2009]
- Fog computing [CISCO 2012]
- Mobile Edge Computing [ETSI 2014]

Cloudlet

- Cloudlet: a nearby offloading site dispersed at the edges of the Internet - Let's bring the cloud closer!

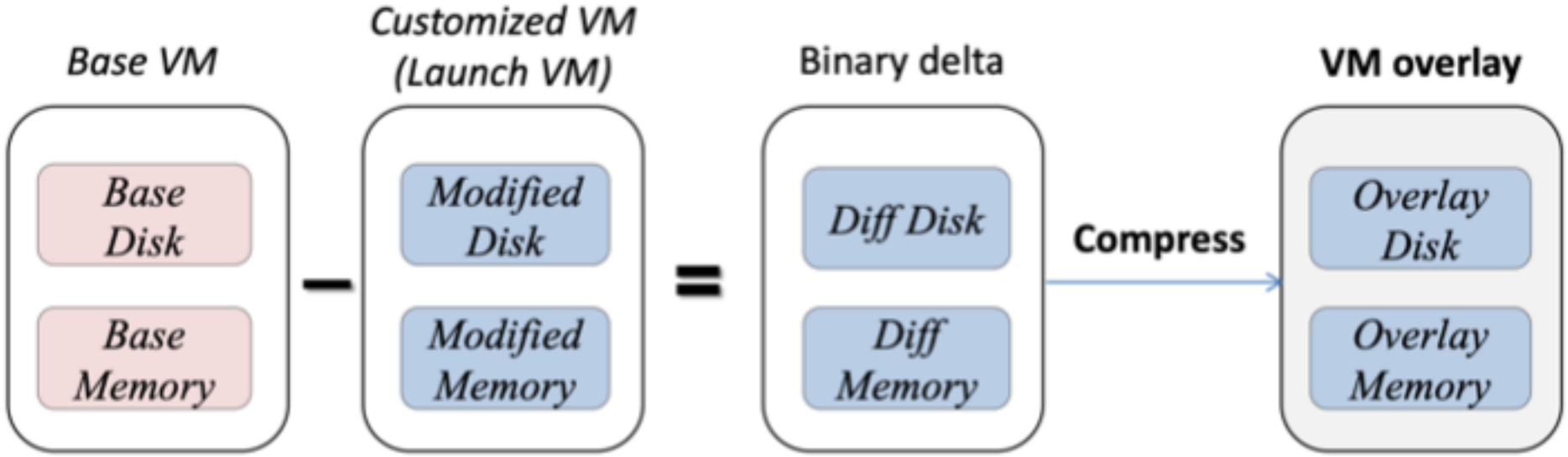


Launch custom back-end server at arbitrary edge

- To make this viable and scalable, we need an edge infrastructure (maybe 3rd party)
  - Wide-area: think mobiles and travel
  - Shared: multiple apps running on the edge
  - Enable any apps in any language in any OS + software libraries, etc.
  - Robust: Secure and Disconnected fallback
- Need to encapsulate apps in VMs

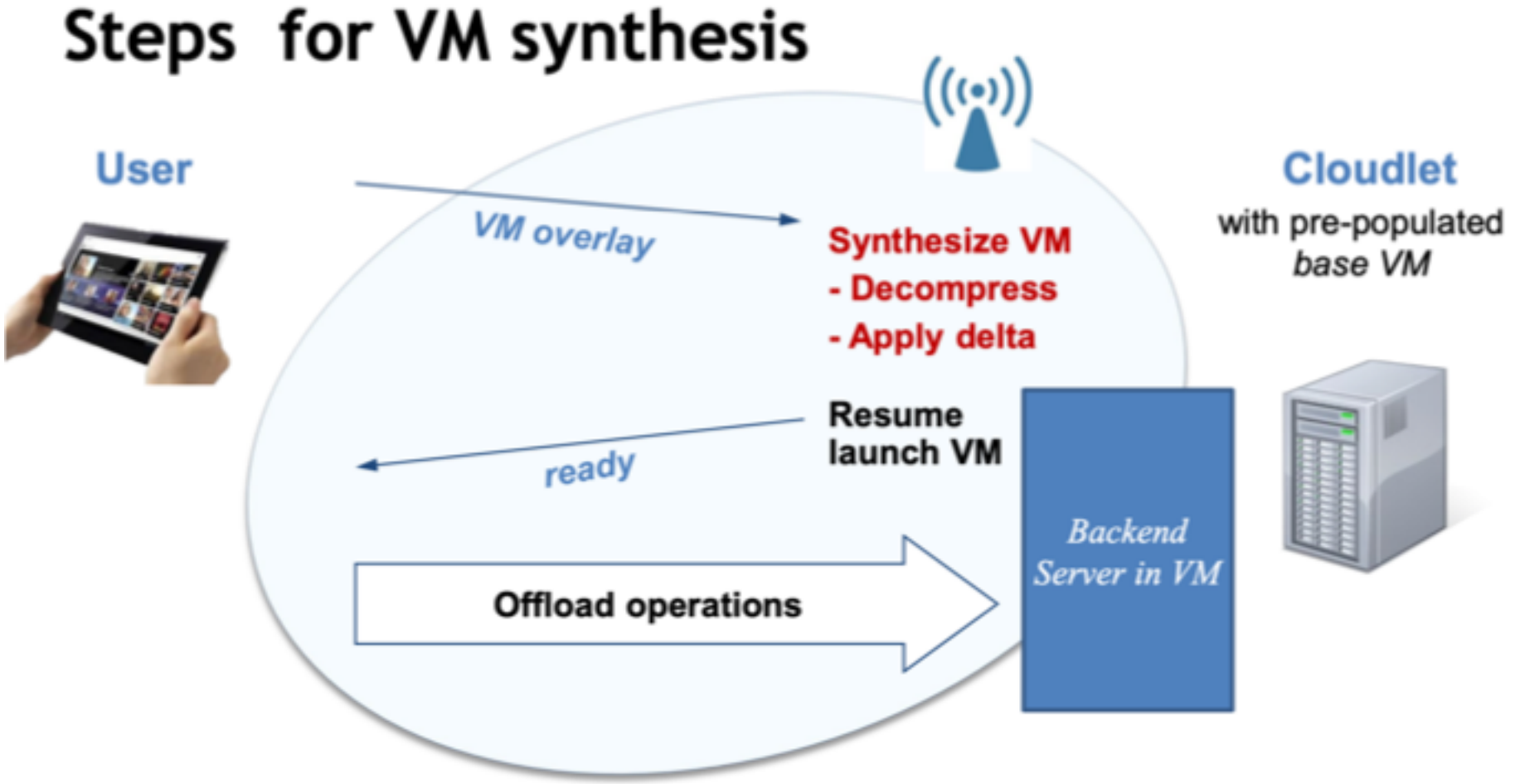
Provision Options

- Static provisioning: Store all possible Virtual Machines on the edge nodes
- Dynamic provisioning: Just-in-Time Provisioning
  - VM Synthesis: dividing a custom VM into two pieces
  - 1) Base VM: Vanilla OS that contains kernel and basic libraries 2) VM overlay: A binary patch that contains customized parts



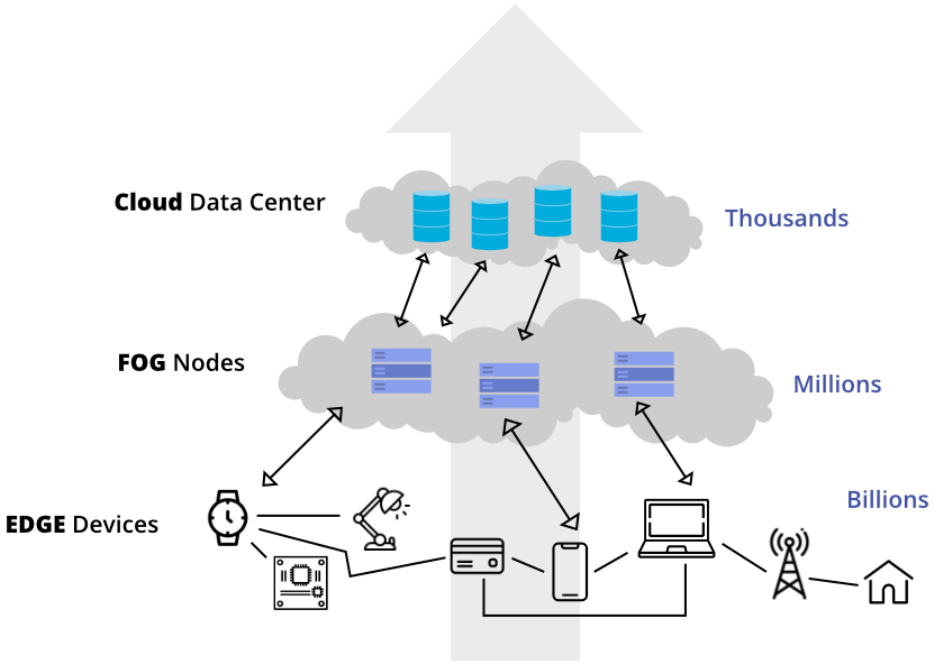
Just-in-Time Provisioning for Cyber Foraging.

VM Synthesis in Realtime



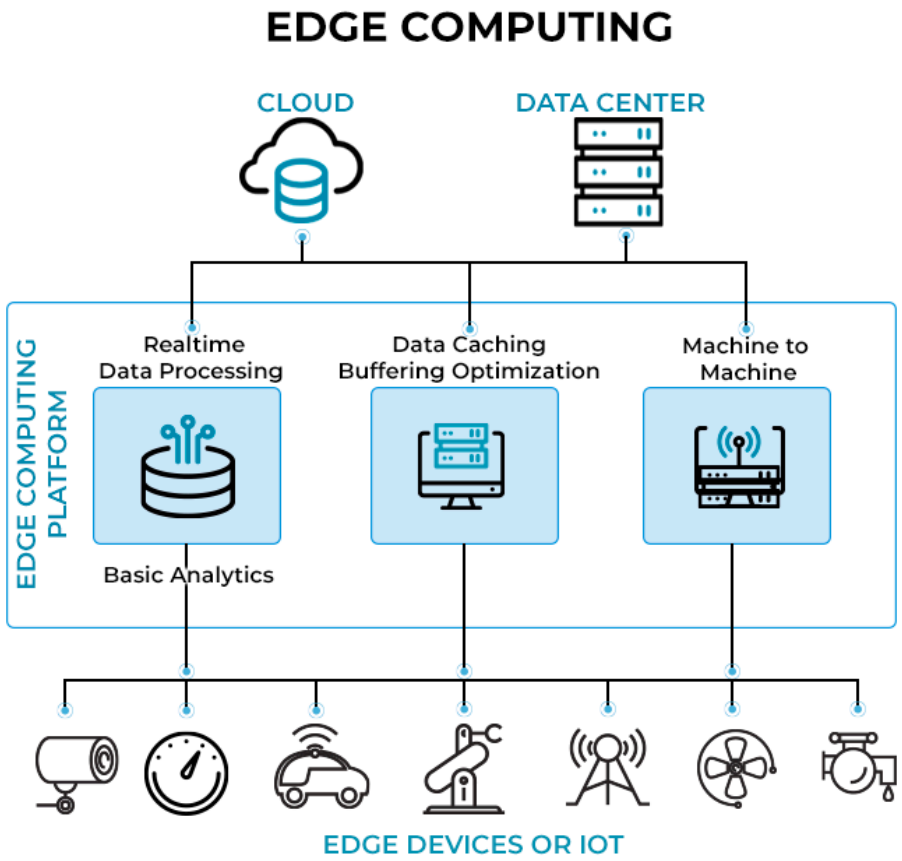
Fog computing

- Create a separate layer to facilitate data transfer
  - Promoted by Cisco in 2012
  - Devices are physically closer to the computational and resource
  - Useful if collaborative task and large amount of resources are used



Edge Computing: The Cloud Provider View

- Goal is mainly to provide
  - Content Delivery Network (CDN) services
  - IoT data processing and aggregation for data in transit to the cloud
- Examples
  - Azure IoT Edge — deploy business logic to edge devices and monitor from the cloud
  - AWS CloudFront — CDN Service, includes Lambda@Edge



Edge Computing: The “Appliance” View

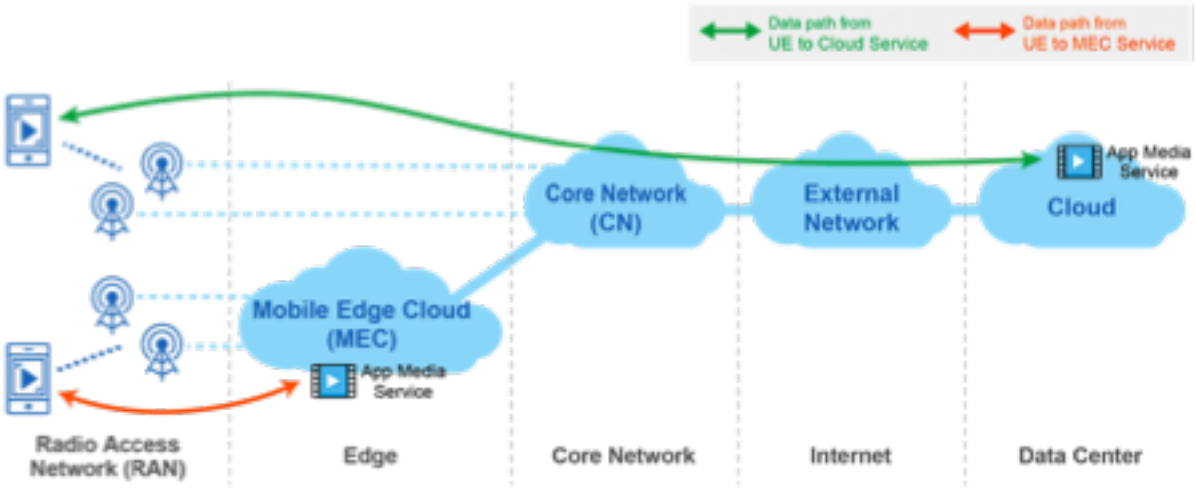
- Goal is to provide a “data center in a box” to push cloud computing capabilities to the edge
  - Often combined with networking capabilities such as edge gateways and smart routers
- Many players in this space, such as Amazon, Cisco, Dell EMC, HPE, etc

AWS Snowball Edge

https://www.govevents.com/blog/2018/11/27/a-new-aws-snowball-edge-provides-the-power-of-the-cloud-in-disconnected-environments/

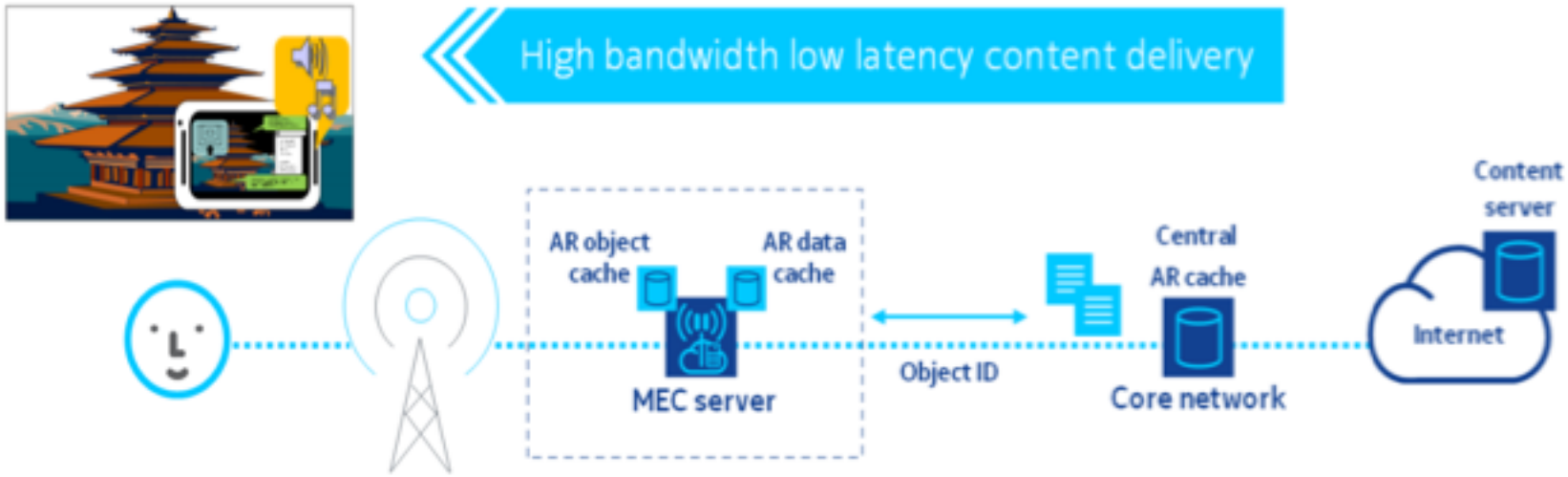
Edge Computing: Telco View

- Opportunity for providing edge computing devices in existing infrastructure
  - e.g., micro data centers at the base of cellular towers
- Multiple organizations seeking standardization: Multi-Access Edge Computing (MEC), Open Edge Computing (OEC), OpenFog consortium, etc.



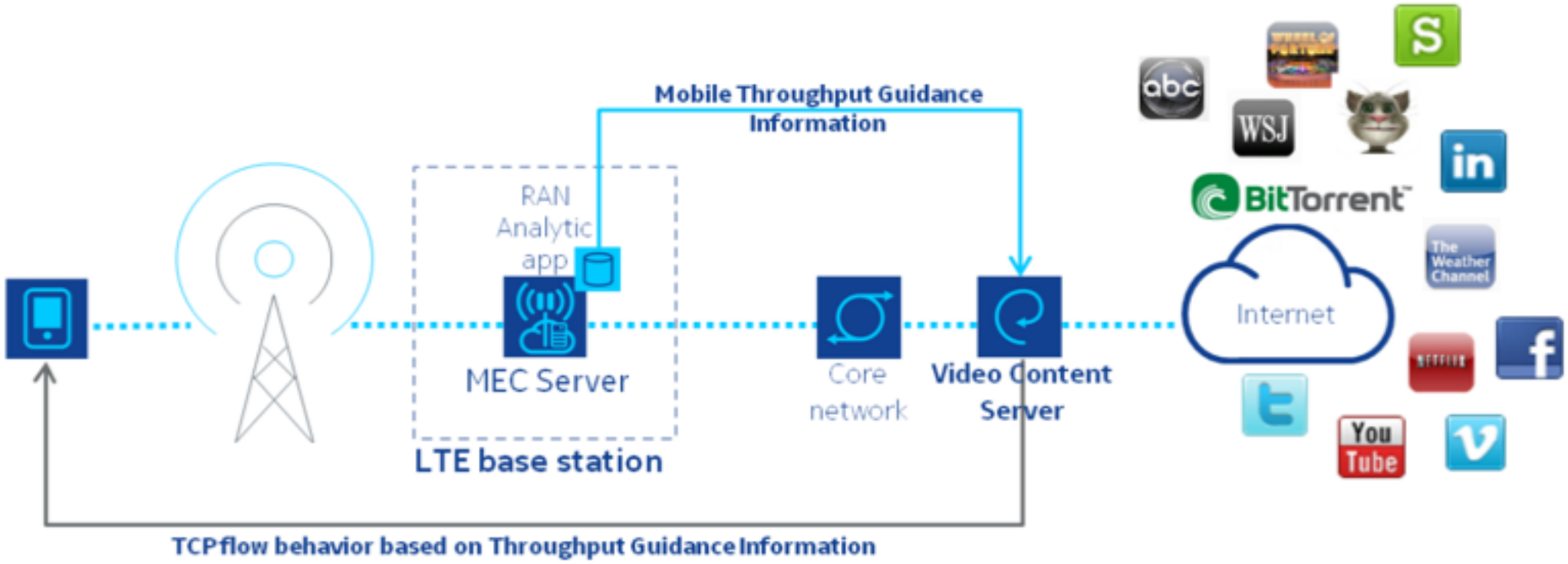
MEC Applications

- Edge-assisted AR/VR application
  - Can choose rendering pipeline either in an edge app or on the UE
  - Can choose to offload part of computation



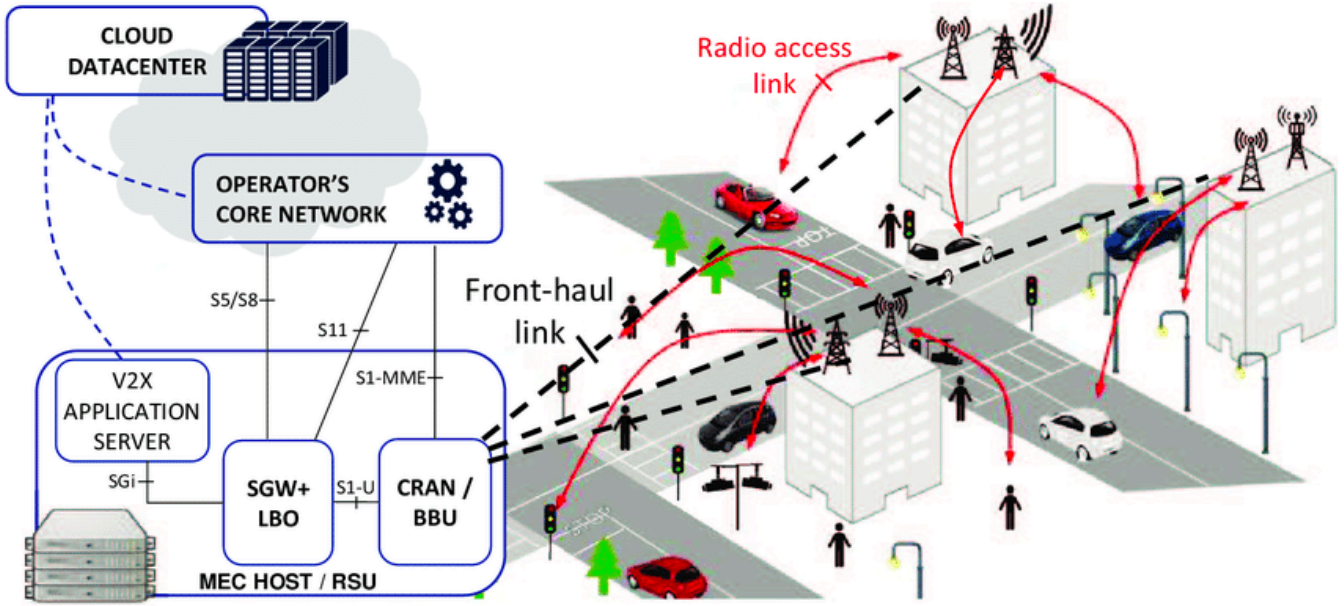
MEC Applications

- Video applications
  - Local content caching, saves the backhaul requirement
  - Quick download of the content improved QoE of video



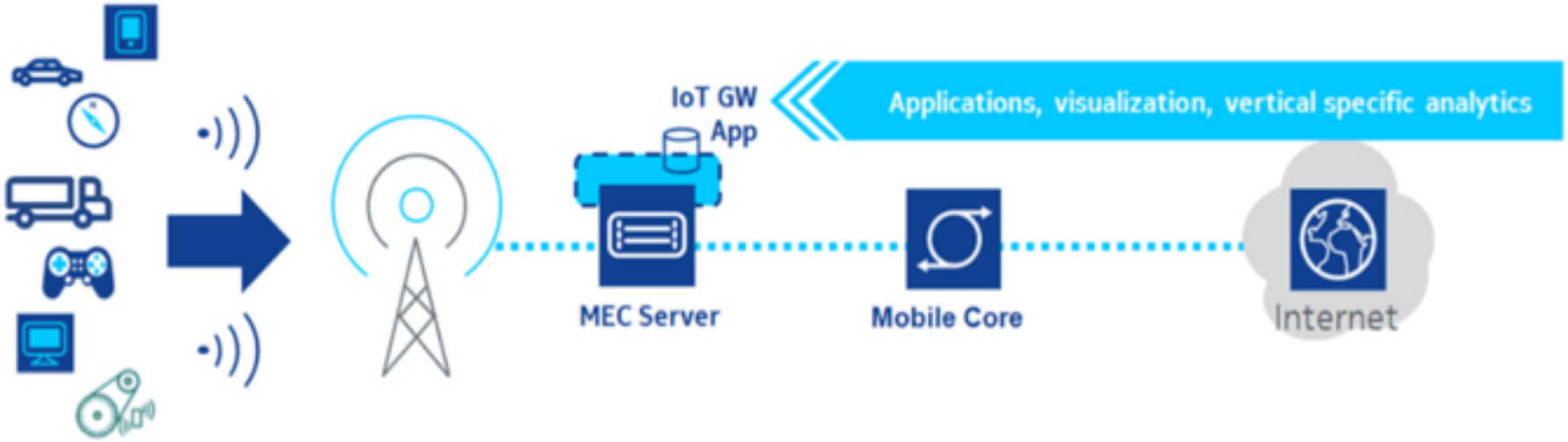
MEC Applications

- V2X (Vehicle to everything)
  - Roadside unit is intended to increase the safety, efficiency, and convenience
  - Data from vehicles and sensors to recognize high-risk situations
  - Tight latency requirements
  - Application can be deployed on ME hosts to provide roadside functionality

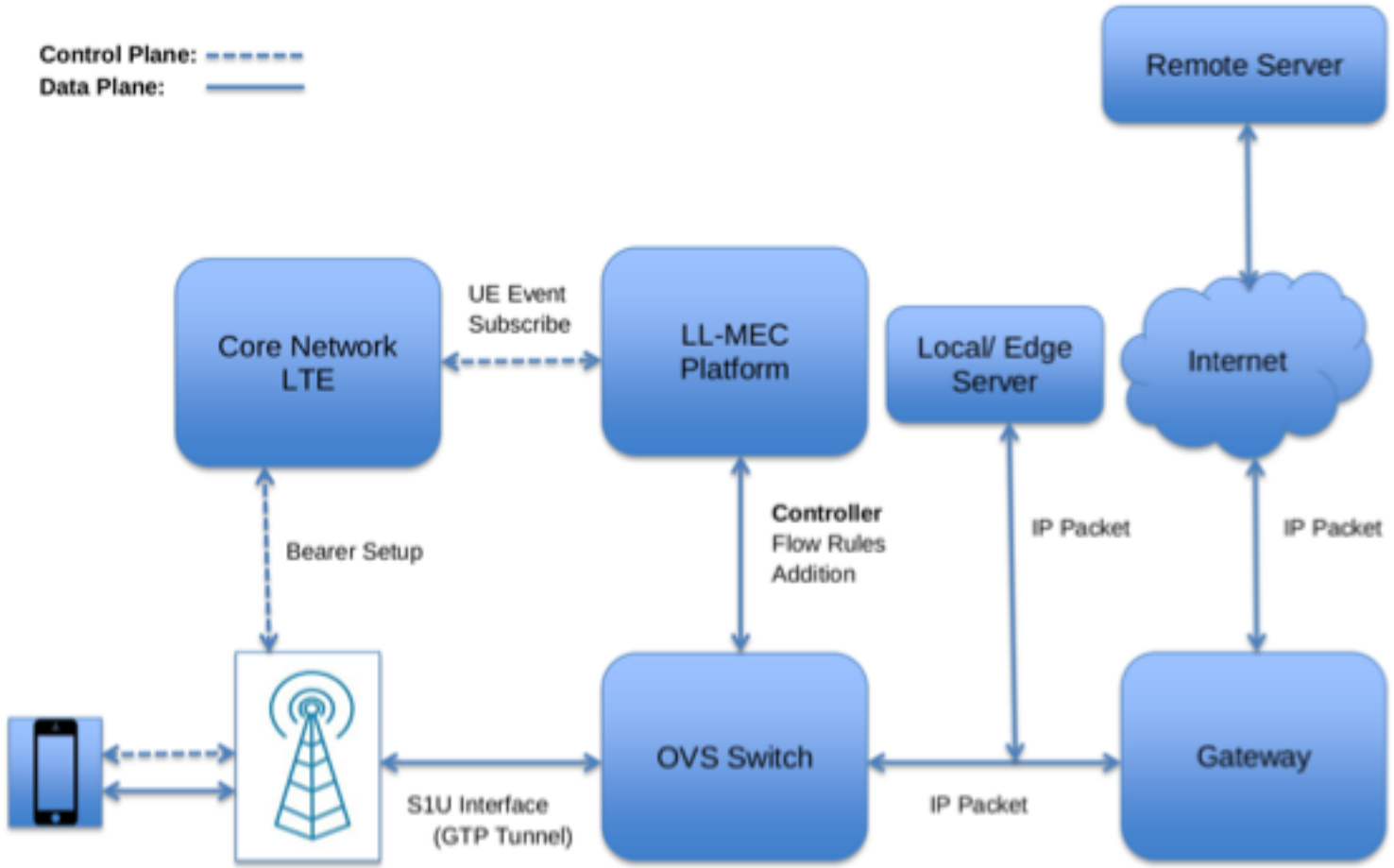


MEC Applications

- MEC-Based IoT gateway
  - IoT Gateway application deployed at MEC server
  - IoT vertical specific data analytics at the edge
  - Data aggregation at the edge



SDN Based MEC in LTE

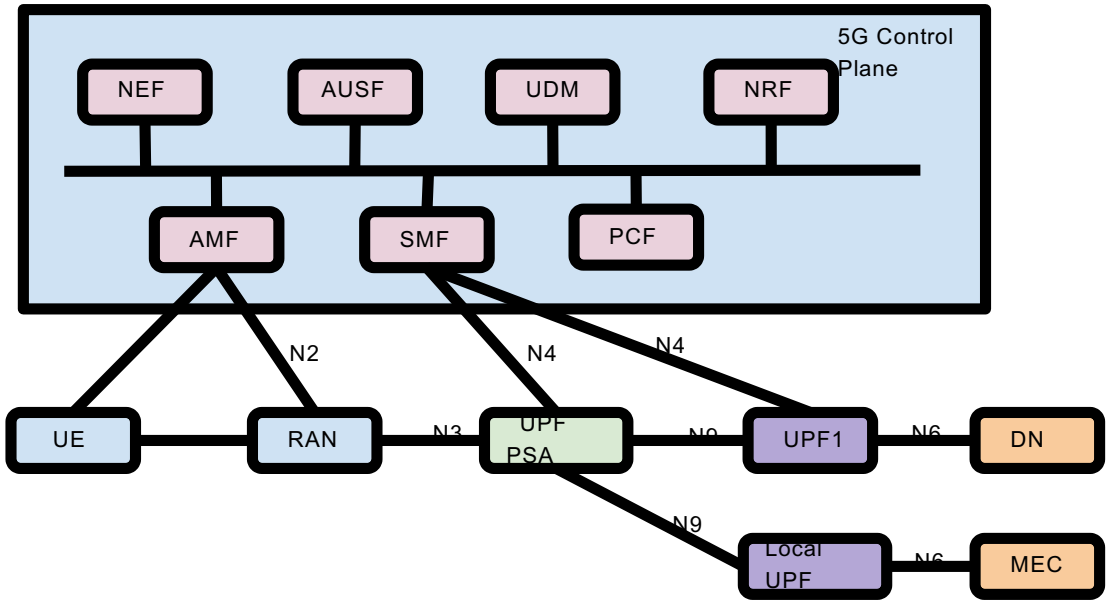


- LLMEC developed by Eurecom for enabling Low Latency Edge Application
- Use of SDN to implement Control and User Plane Split (CUPS)
- Use of northbound APIs for traffic redirection
- Moving PGW functionalities at OpenVSwitch for traffic steering

MEC in 5G

- 5G provides higher data rate than 4G (1000x bandwidth per unit area) -> more back haul traffic in the 5G core
- 5G RAN provides low RAN latency (1 ms) -> Backhaul is the bottleneck for the low latency services

MEC Deployment



Multiple UPF support: One UPF for MEC and one UPF for DN