meSDN: Mobile Extension of SDN

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Very brief on SDN

- Networks are very hard to manage and evolve.
- Data Plane:

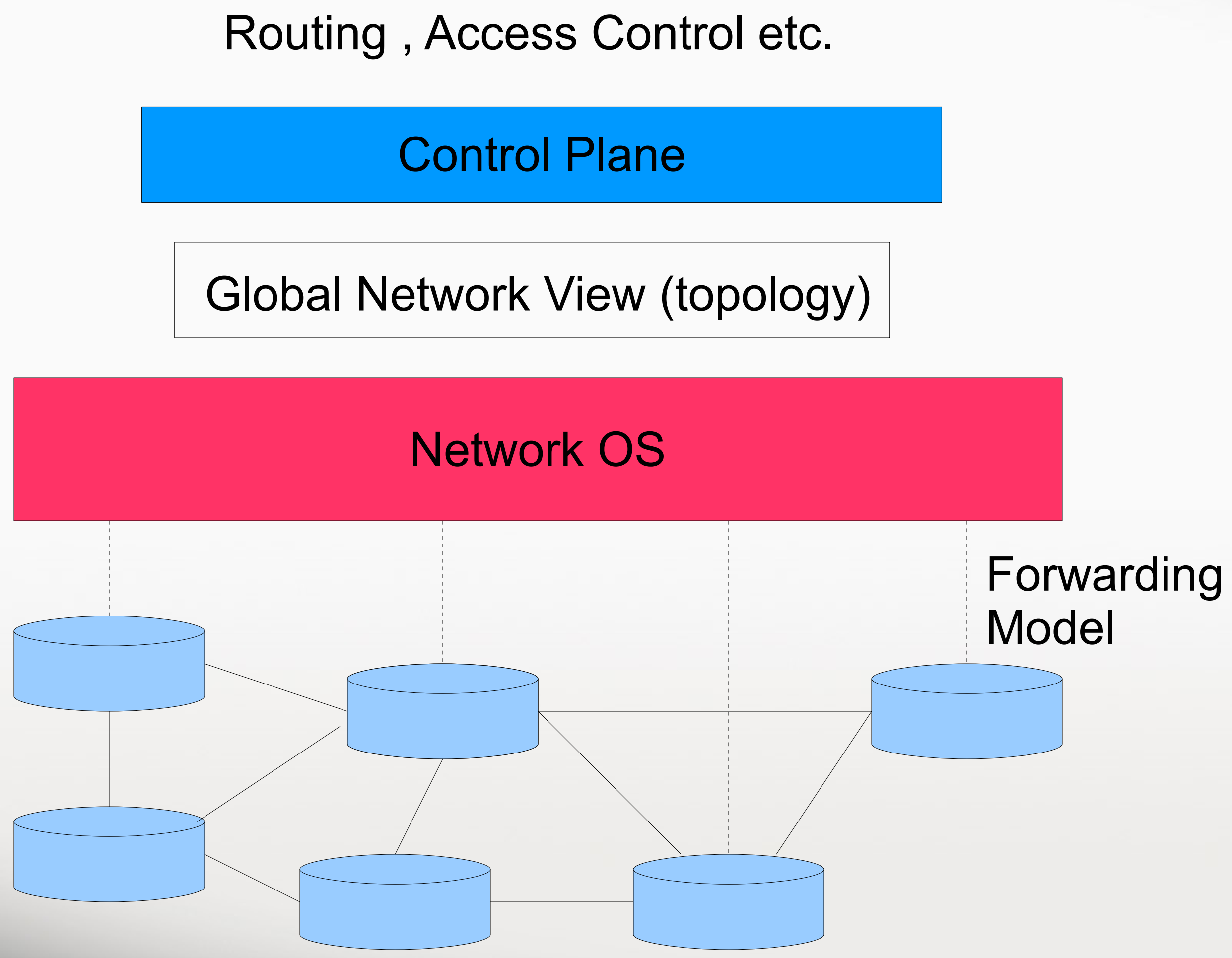
  Fwding state + Packet header → forwarding decision

  Fast(nano-scale) and local.
- Control Plane:

  Compute the forwarding state for the data plane.

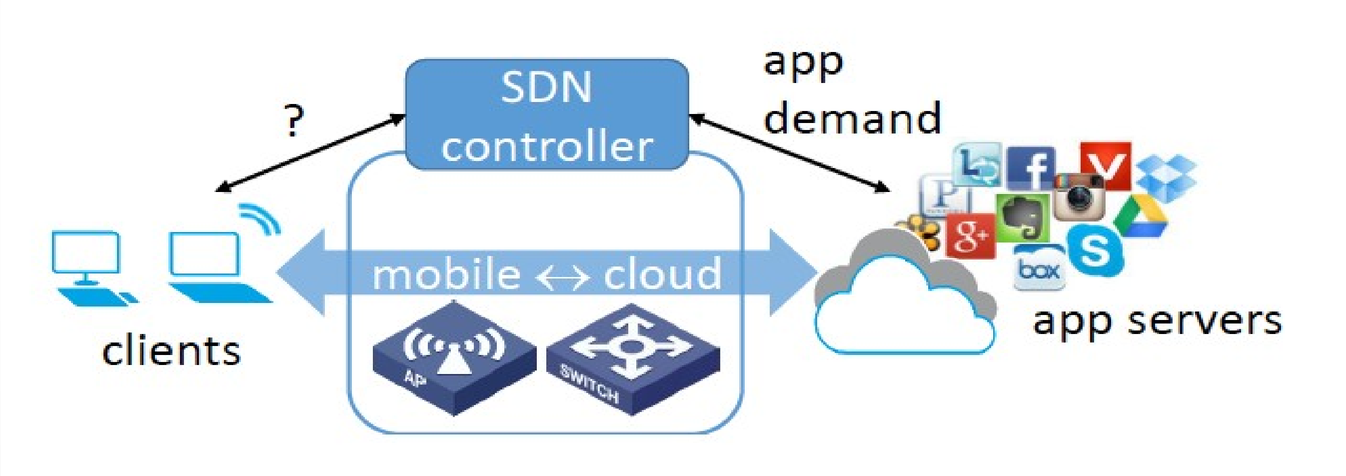
  Routing, Isolation, Traffic engineering.
- Control Plane mess is the root cause of SDN.

SDN: A layer of two Control Plane Abstraction



Mobile Cloud Application

- Mobile cloud application require guaranteed network performance.

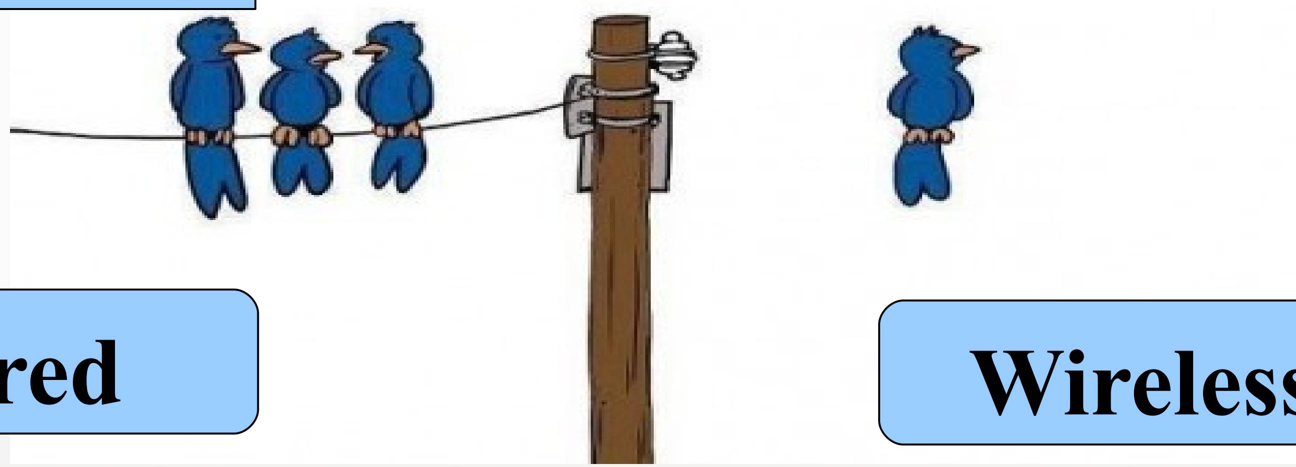


- SDN controller need to provide performance guarantee to clients knowing the app demand from the cloud server.

SDN in Wired and Wireless

We can provide performance Guarantee by controlling Network edge

I can't :(



Wired

- Point-to-Point full Duplex link.
- End device Tx don't interfere with others.

Wireless

- Shared half-duplex medium.
- Can't control client's uplink Tx.

Pushing SDN to Clients

- Existing SDN framework stops at network edge.

- Highly predictable performance for client device.
  - SDN enable AP (OpenRadio and OpenRAN) cannot guarantee wireless resource for uplink from the client.

- End-to-end QoS control.
  - e.g. One client greedily using highest priority can unfairly dominate uplink air-time resource.

Our Solution: *meSDN*

- *meSDN* (mobile extension of SDN): extend the SDN framework to the end device.
- *meSDN* allows the control-plane of wireless network to be extended to mobile device.
- Provide fundamental software-defined solutions for many applications
  - WLAN virtualization, application-awareness, E2E QoS, and network troubleshooting.

meSDN: Smartness in End-Devices

- Ground-truth information about client application information.
- Monitor and manage mobile application's traffic flows real-time.
- Guarantee airtime resource.
- Provide end-to-end QoS service for mobile clients.

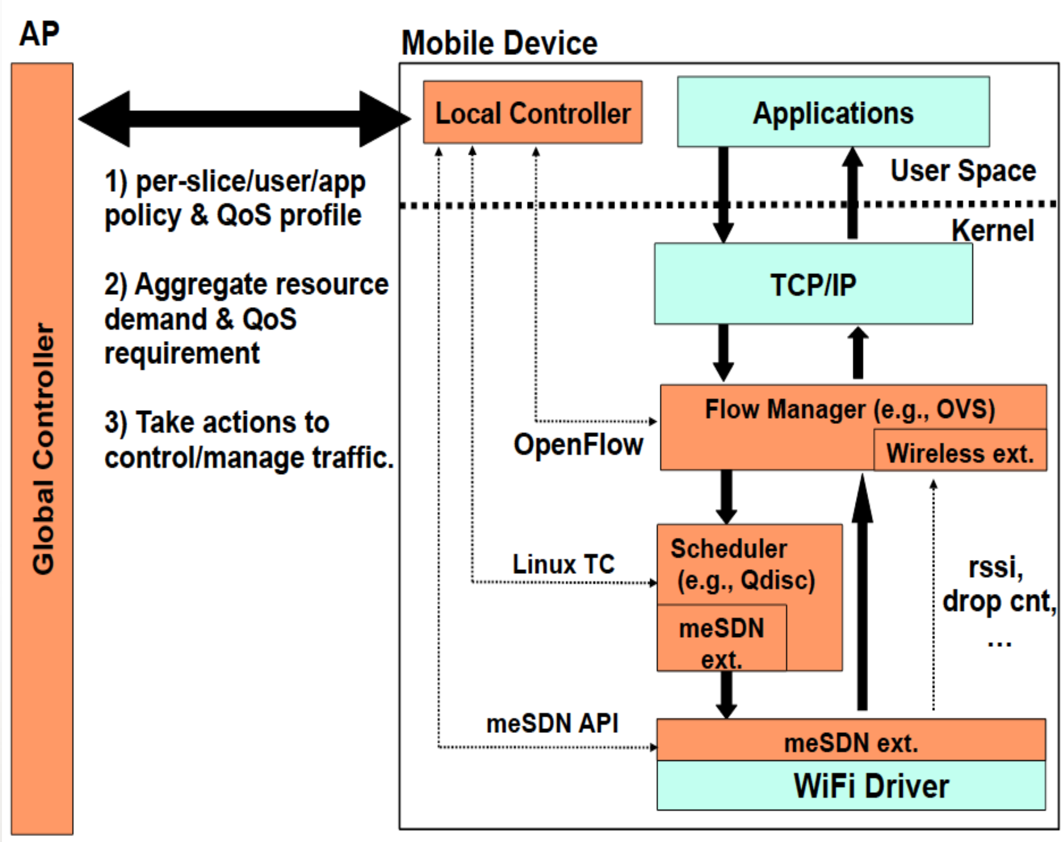
Agent @ Mobile endpoints!

- Not a new concept to centrally control the client devices
  - (e.g. PC COE, BYOD solutions, VPN client, mobile WAN acceleration).

- Allows several benefits:
  - Users can have better and predictable network performance.
  - SDN controller can enforce policies directly on the client's traffic.
  - Support enhance network security, end-to-end QoS and WLAN virtualization.

meSDN Architecture

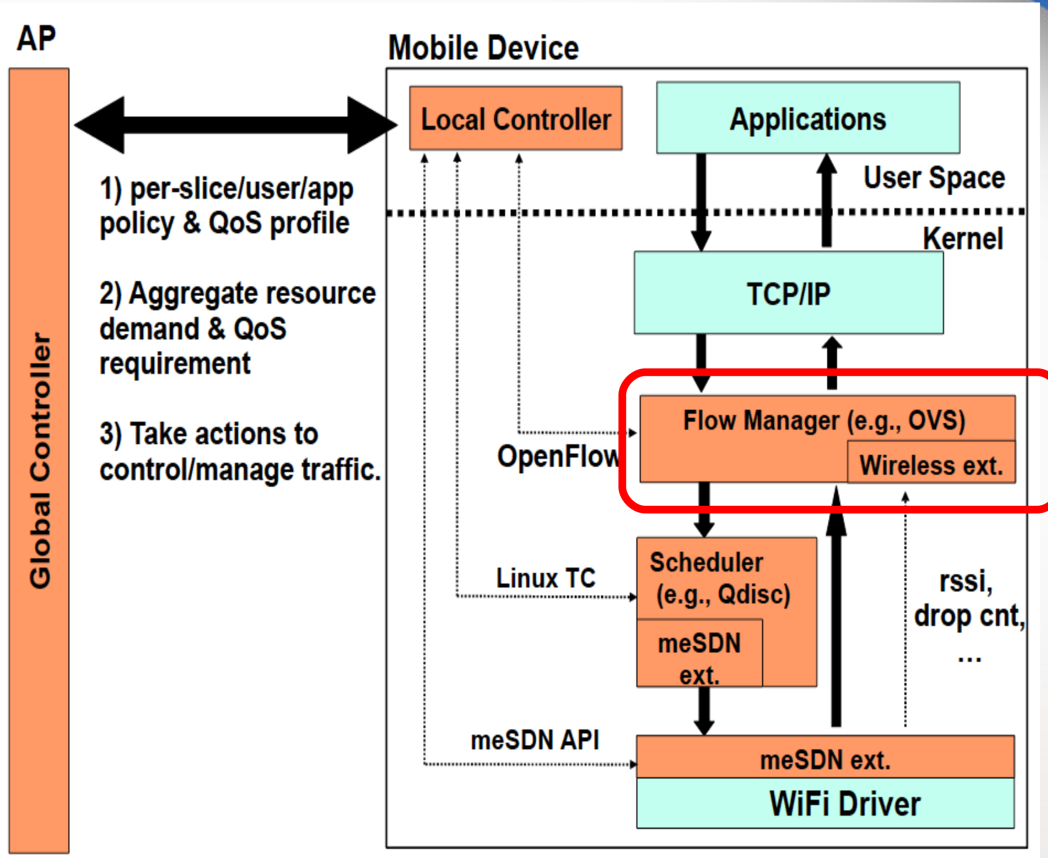
- Flow Manager (e.g. Open vSwitch, OVS).
- Scheduler (e.g. Linux multi Qdisc).
- Local Controller (e.g. Android userspace software/agent).
- Global Controller.



meSDN Architecture

meSDN: Flow Manager

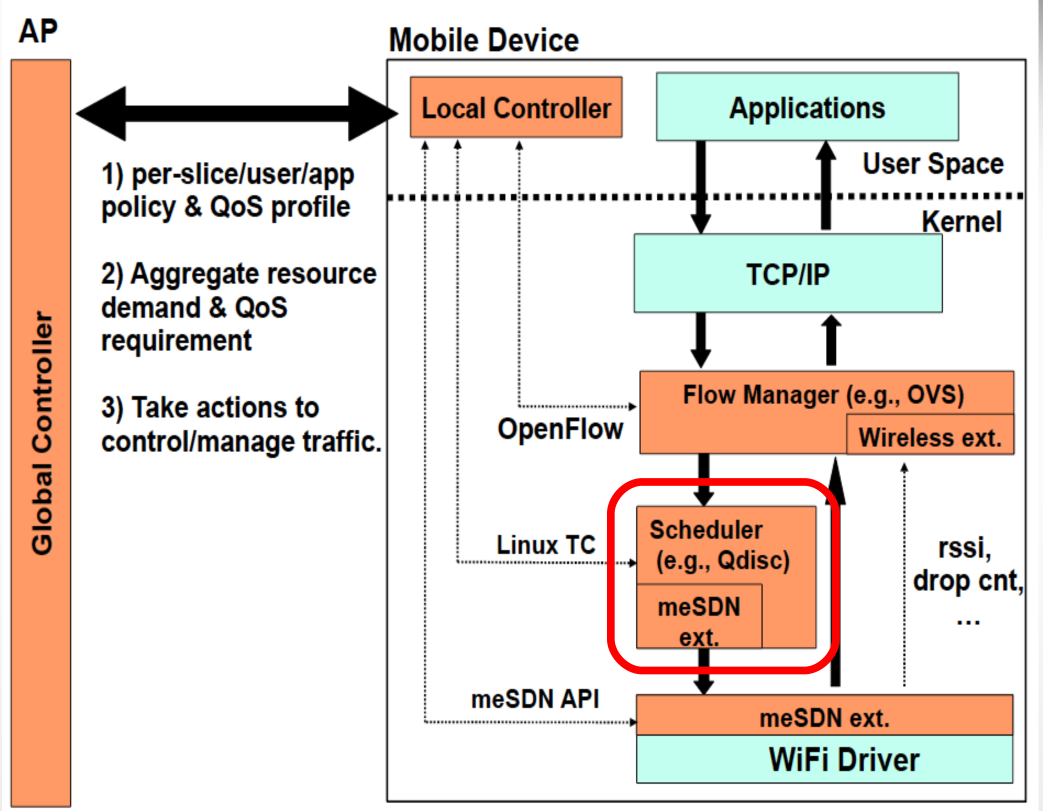
- It is a software OpenFlow switch (e.g. OVS)
- Collect Flow statistics:
  - OF Stat extension: burst duration, burst rate and inter-burst time.
- Enforce SDN policies e.g., correct QoS marking
- Interact with the WiFi Driver to configure.



meSDN Architecture

meSDN: Scheduler

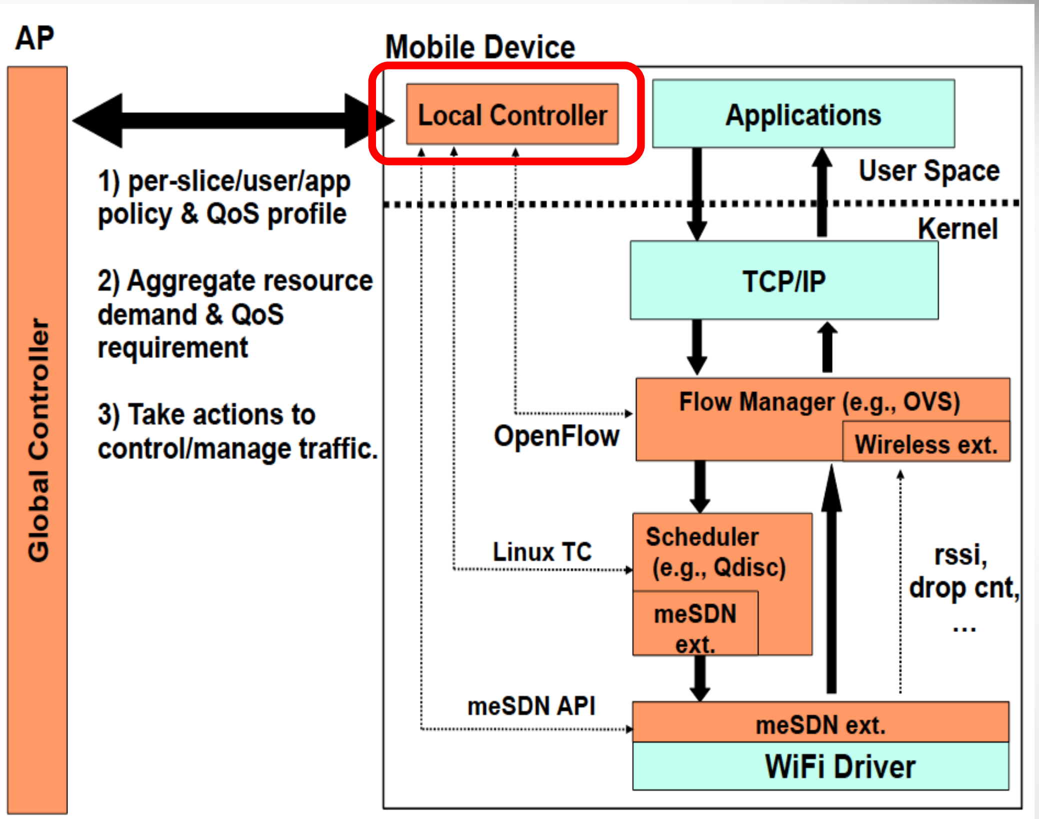
- Extension to linux multiq or WiFi Driver that supports 802.11e QoS.
- Receive *time window* from the local controller to start/stop dequeueing.
  - Time Window: e.g. [Start time, active duration, sleep duration]
  - e.g. 05:30:30, 10ms, 30ms



meSDN Architecture

meSDN: Local Controller

- Identify flows correspond to each application.
- Generate flow rules for OVS
  – Based on per-application policy given by central controller or the user.
- Read per-flow statistics from Flow Manager.
  - OpenFlow extension.
- Control the scheduler.

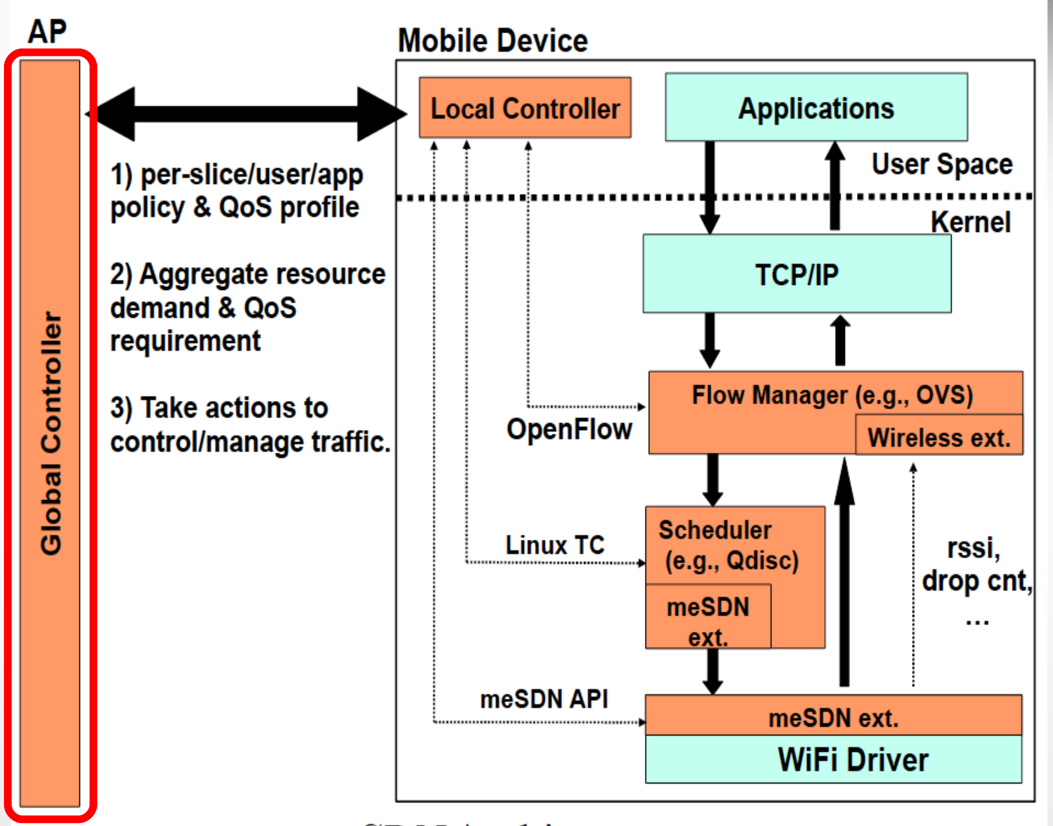


meSDN Architecture

meSDN: Global Controller

Interacts with local controller

- provide per-slice, per-user, per-application policies and QoS profiles.
- Collect 'aggregated' airtime demand of the running applications and QoS requirements.
- Apply proper action back to the local controller(e.g. Scheduling)



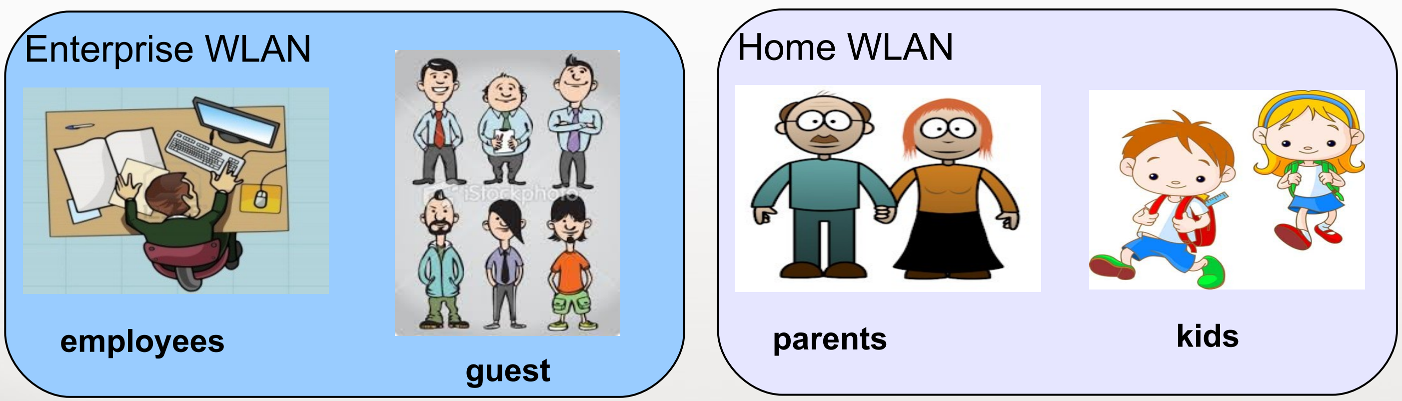
meSDN Architecture

meSDN: Use-Cases / Applications

- Realtime detection/analysis of networks flows.
- Network fault diagnosis and trouble shooting.
- WLAN virtualization.
  - Guarantee airtime resource to multiple group of users.
- Dynamic Policy Setting.

WLAN Virtualization

- WLAN virtualization enable effective sharing of wireless resources by a diverse set of users with diverse requirement



*p*TDMA: WLAN Virtualization

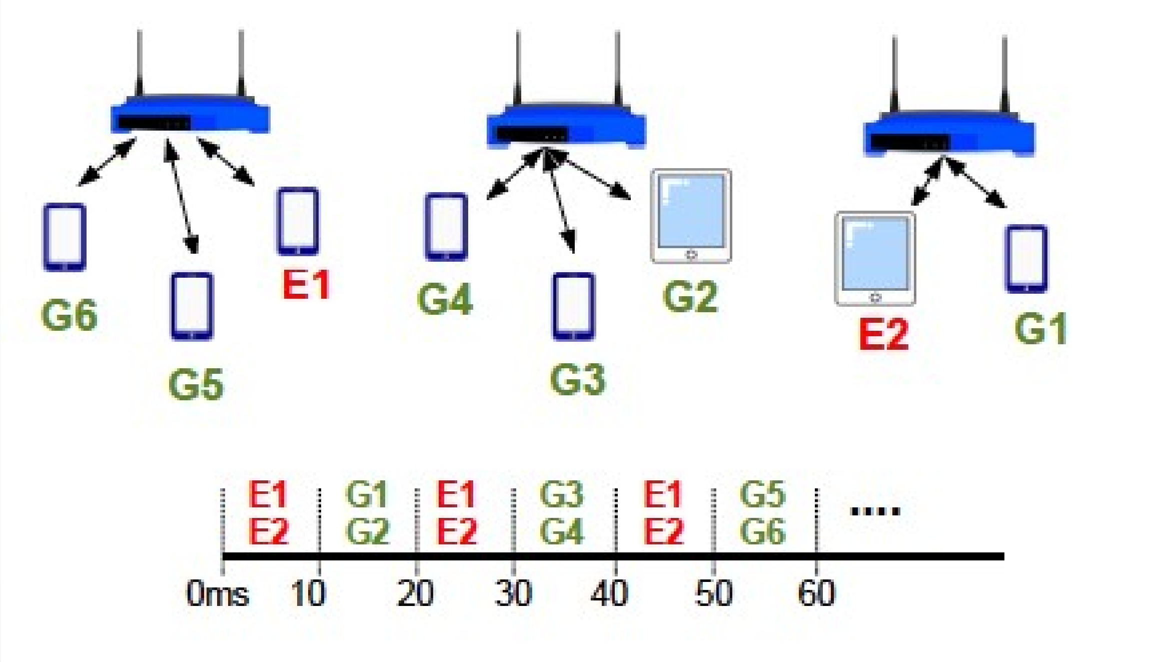
- *p*TDMA is a simple prototype of *meSDN for* WLAN virtualization service.

- Manage airtime share between network instances (their clients) that collocate in space and channel
  - Assigning separate airtime slices among different network instances

*p*TDMA: Scheduling Principles

- Allocate large enough time window to transmit and receive multiple packets.
- Schedule multiple clients in a common slot to maximize channel utilization.
- The interval between consecutive time windows should be based on applications' traffic pattern & demand.

*p*TDMA: Prototype Scheduling



- 50:50 airtime share between employee network and guest network.
- Every time window is fixed of 10ms.

*p*TDMA: Implementation

- Prototyped *meSDN* client-side component on eight Google Nexus 4 Android phones
- Root the device to install OVS and *p*TDMA qdisc kernel modules.
- Re-Build the kernel image
  - To implement the Wi-Fi driver byte limit in Nexus 4 WiFi driver
  - Note: some other phones have Wi-Fi driver as kernel module (e.g. Nexus S)

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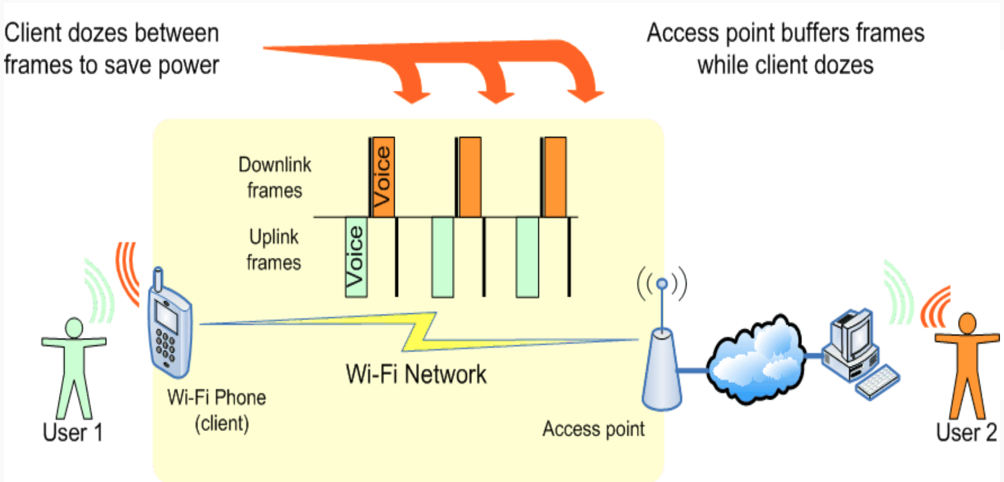
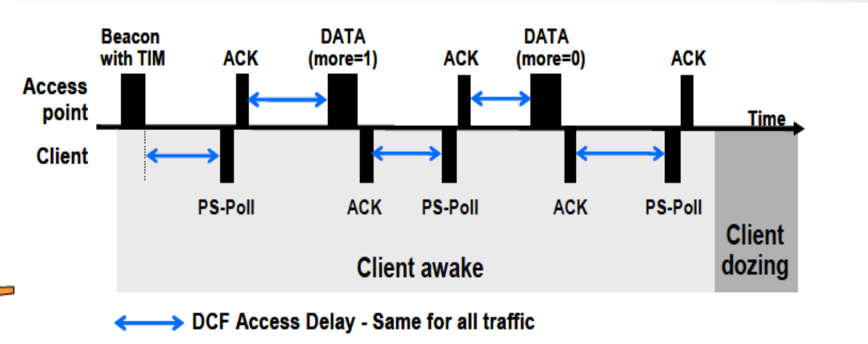
*p*TDMA: Downlink Control and Power Saving

WMM Power Save in a Wi-Fi Network



Wi-Fi legacy power save



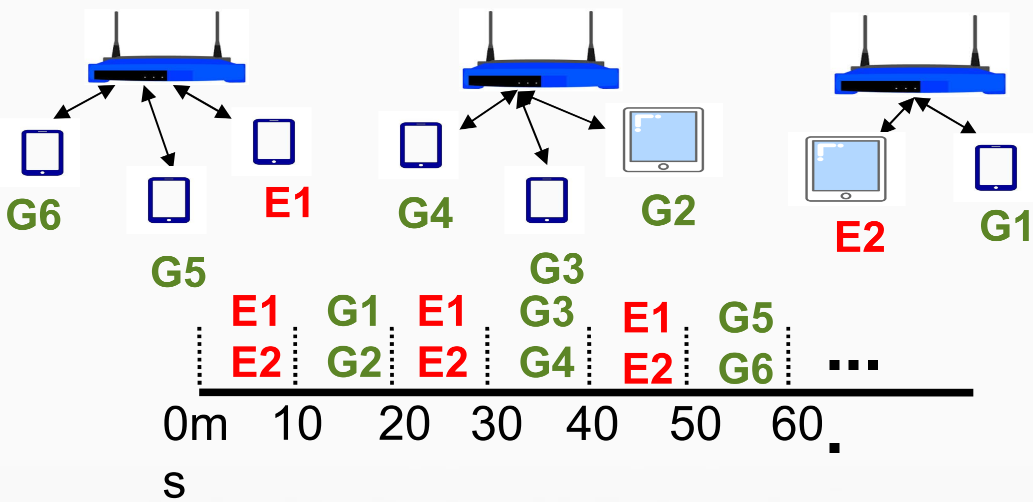
1. *meSDN* leverage WMM-PS to indirectly confine the downlink traffic to the time window.

2. *p*TDMA allows to efficiently utilize the WMM-PS to have more sleeping time without sacrificing the throughput performance.

*p*TDMA: Implementation Challenges

- Milli-second level synchronization between the phones is needed for effective *p*TDMA.
  - Achievable by GPS
  - Note: traditional per-packet TDMA requires micro-second level time sync
- Driver buffering delay is large.
  - Bufferbloat: Large ring packet buffer (100 to 300, total bytes >150KB) used by WiFi, Ethernet drivers
  - Byte Queue Limit(BQL) for Ethernet driver in Linux: buffer size limit is dynamically set based on recent "byte" dequeued by the NIC
  - We set hard byte limit in Wi-Fi Driver to 15KB, enough for 10 pkt 802.11 aggregation

*p*TDMA: Experiment



We formed two network slices

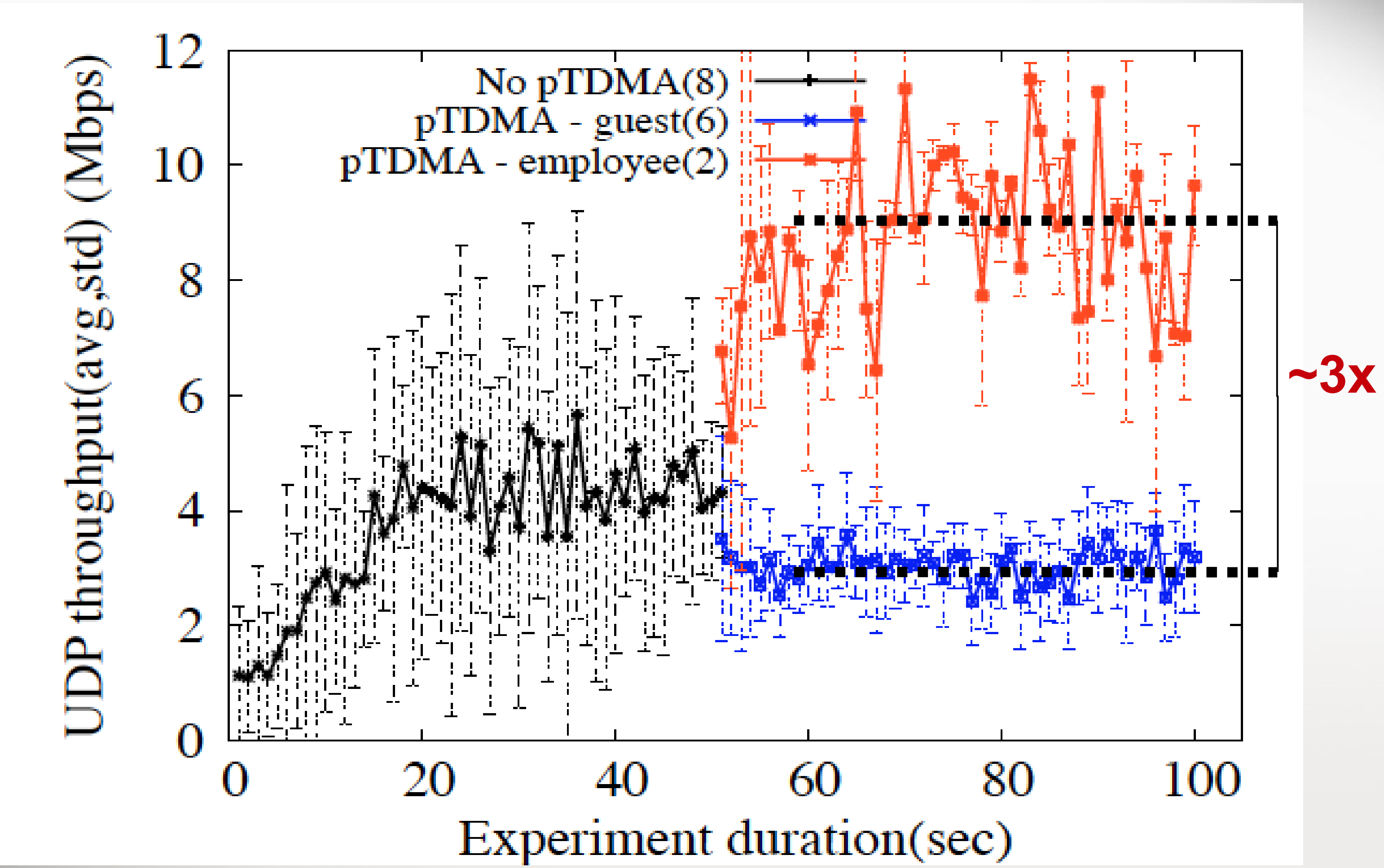
"employee" network with 2 devices

"guest" network with 6 devices

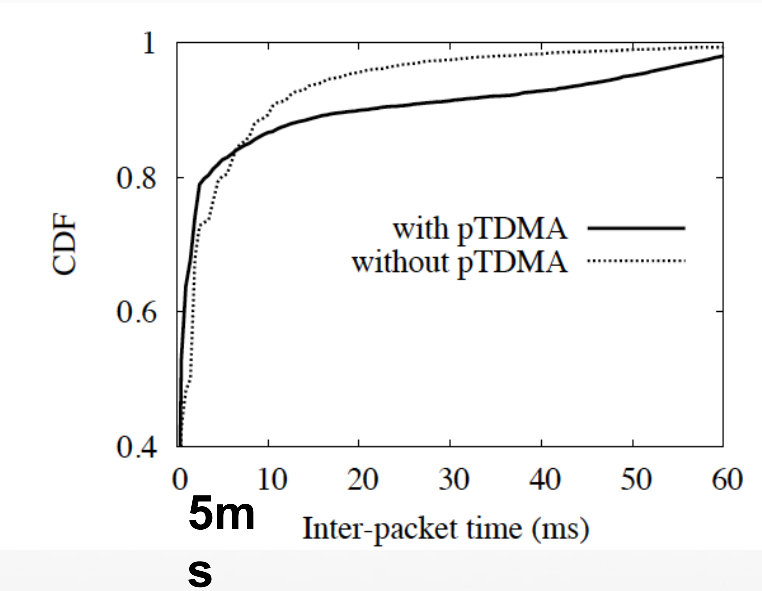
Applied following *p*TDMA schedule with 50:50 airtime share between two slices

– 3:1 airtime ratio btw an employee and a guest.
(but all devices are connected to one AP)

*p*TDMA: Evaluation (ulink UDP)



*p*TDMA: Evaluation (Sleeping Time)

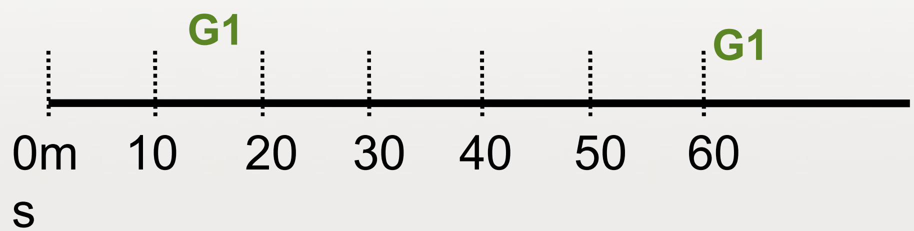


Assume the driver goes to sleep state after 5ms of inactivity in WMM-PS

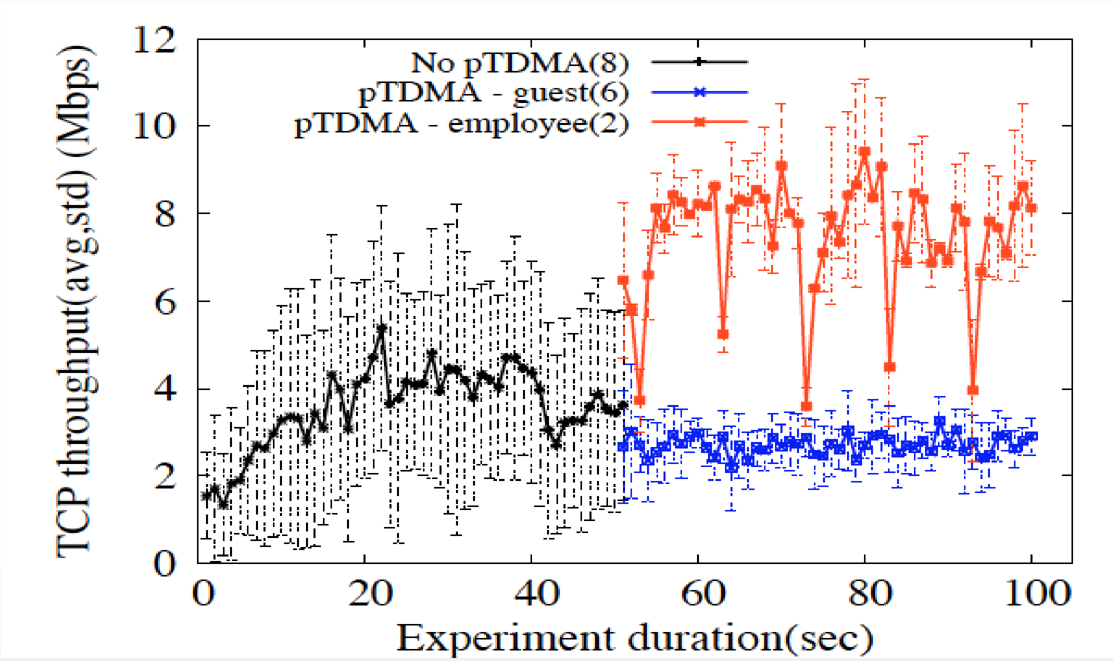
In non-*p*TDMA, client sleeps 28% of the time.

In pTDMA, client sleeps 80% of the time

Client device *p*TDMA schedule



*p*TDMA: Evaluation (uplink TCP)



Increased transmission time in pTDMA schedule do not adversely effect TCP performance.

Related Work: WLAN infra virtualization

- Multiple SSID networks
  - Don't guarantee wireless resource share to each SSID network
- SDN enable AP(OpenRadio, OpenRAN, Odin, CloudMAC).
  - No control on uplink traffic from client.
- Tuning 802.11e QoS parameters in AP
  - Limit the virtual network to four QoS classes.

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Related Work: Client Side Solution

- Per-packet TDMA MAC to virtualize airtime.
  - Clock Synchronization among devices.
  - Hardware control from driver/firmware.

- SplitAP loosely control uplink
  - Under Utilization of airtime

- Deployed OVS to utilize multiple network interface.

In Summary

- Extending SDN capabilities to mobile end device.
- Propose and demonstration of *meSDN* framework.
- As a proof-of-concept, we implement *p*TDMA for WLAN virtualization service.

Thank you

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Jean Tourrilhes