Multi-access Edge Computing over Fiber Wireless Networks for 5G Era

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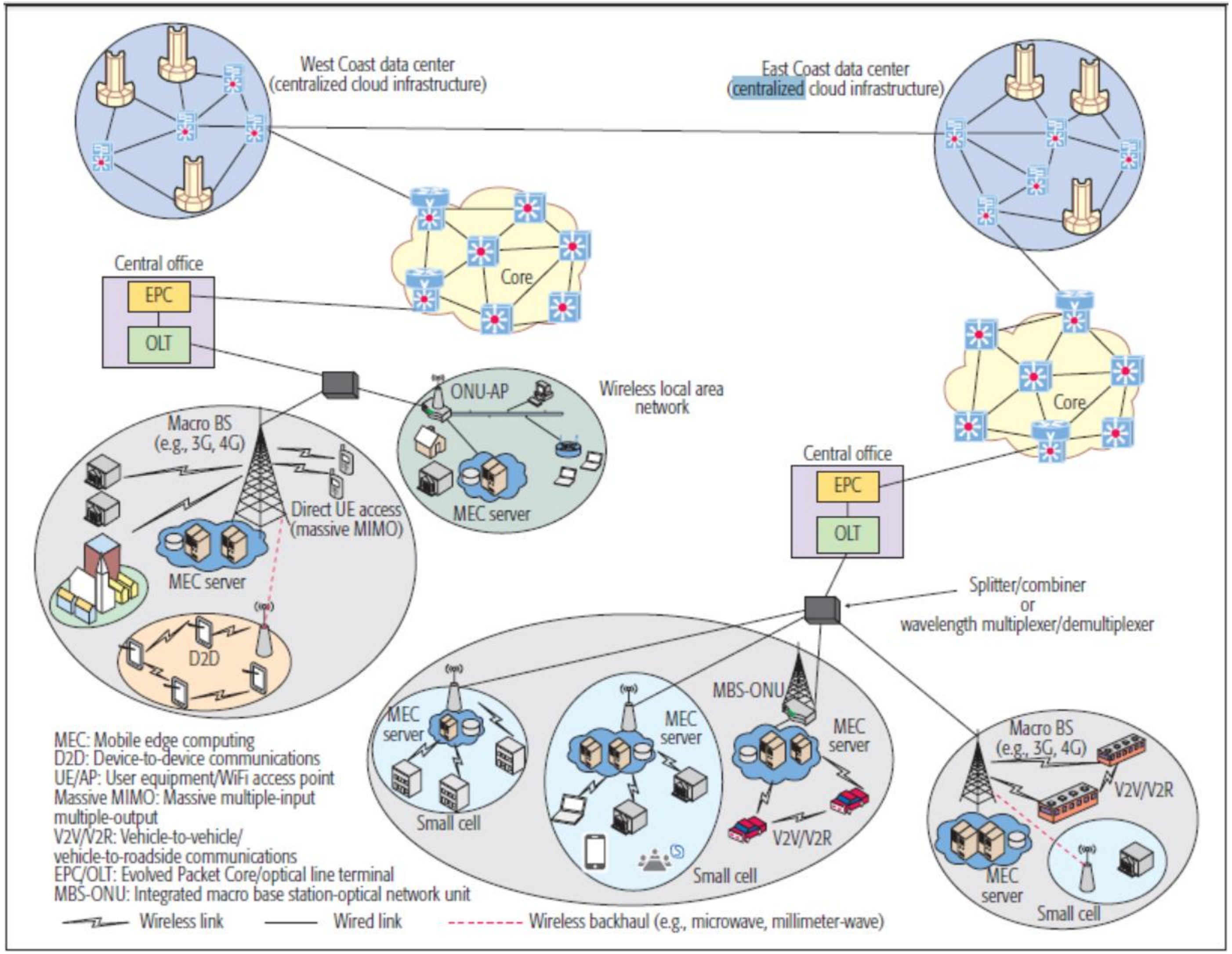
B. P. Rimal, D. P. Van and M. Maier, "Mobile Edge Computing Empowered Fiber-Wireless Access Networks in the 5G Era," in *IEEE Communications Magazine*, vol. 55, no. 2, pp. 192-200, Feb. 2017.

MEC over FiWi: Architecture



MEC over FiWi: Architecture

- FiWi networks: optical networks as backhaul + RAN as fronthaul
- FiWi can be built using any optical access networks, for example, EPON and next-generation PON in the backhaul segment, and RAN technologies in the front-end segment, such as Gigabit-class IEEE 802.11ac very high throughput (VHT) WLAN, and 4G LTE/LTE-A.

- Two implementation options for MEC over FiWi

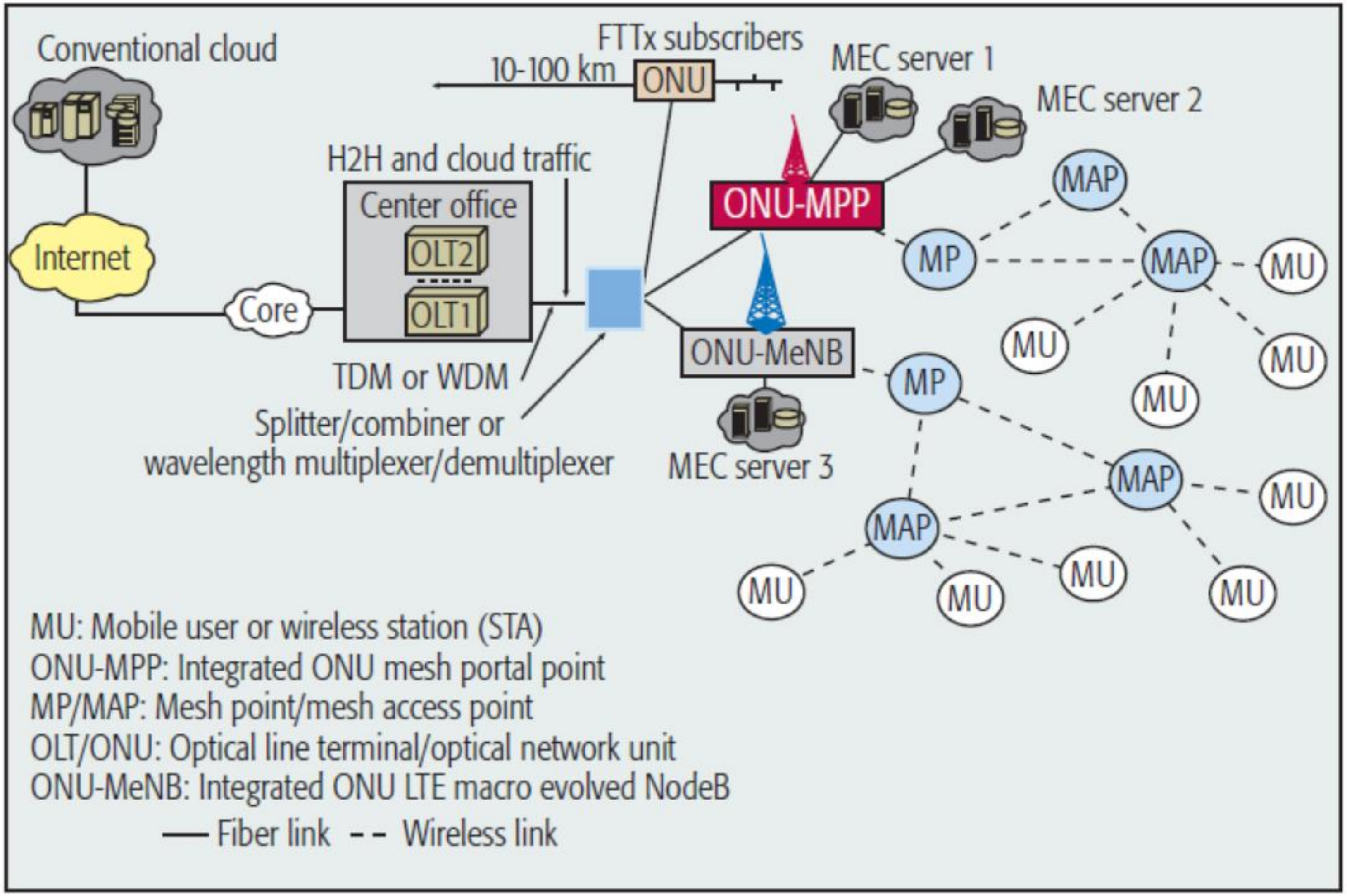
- Option A: Ethernet-based FiWi network may rely on the emerging cloudlet enhanced distributed RAN (D-RAN) based on so-called radio-and-fiber (R&F) technologies. In cloudlet enhanced D-RAN, the functionalities of remote radio heads (RRHs) and baseband units (BBUs) are split, whereby RRHs and BBUs are linked via an Ethernet interface and the baseband processing is done at a MEC server.

MEC over FiWi: Architecture(cont.)

- Option B: A FiWi network can be realized via radio over fiber (RoF) technologies such as C-RAN. In C-RAN, BBUs that connect a number of macro BSs or small cells (i.e., femto-, picocell) are centralized with pool baseband processing (i.e., BBU pool), while RF signal is digitized and transmitted over optical fiber for fronthauling (i.e., between RRHs and BBUs)

- MEC over FiWi networks can be realized by enabling cloud computing capabilities using, for example, a powerful rack server or cloudlets directly connected to the integrated ONU-mesh portal point/access point (AP) (i.e., at the edge of FiWi networks). Even though MEC servers could be deployed at different locations in FiWi networks such as at a central office or anywhere along the backhaul segment, the most important design principle is that MEC servers should be in close proximity to subscribers.

MEC over FiWi networks: Case 1&2



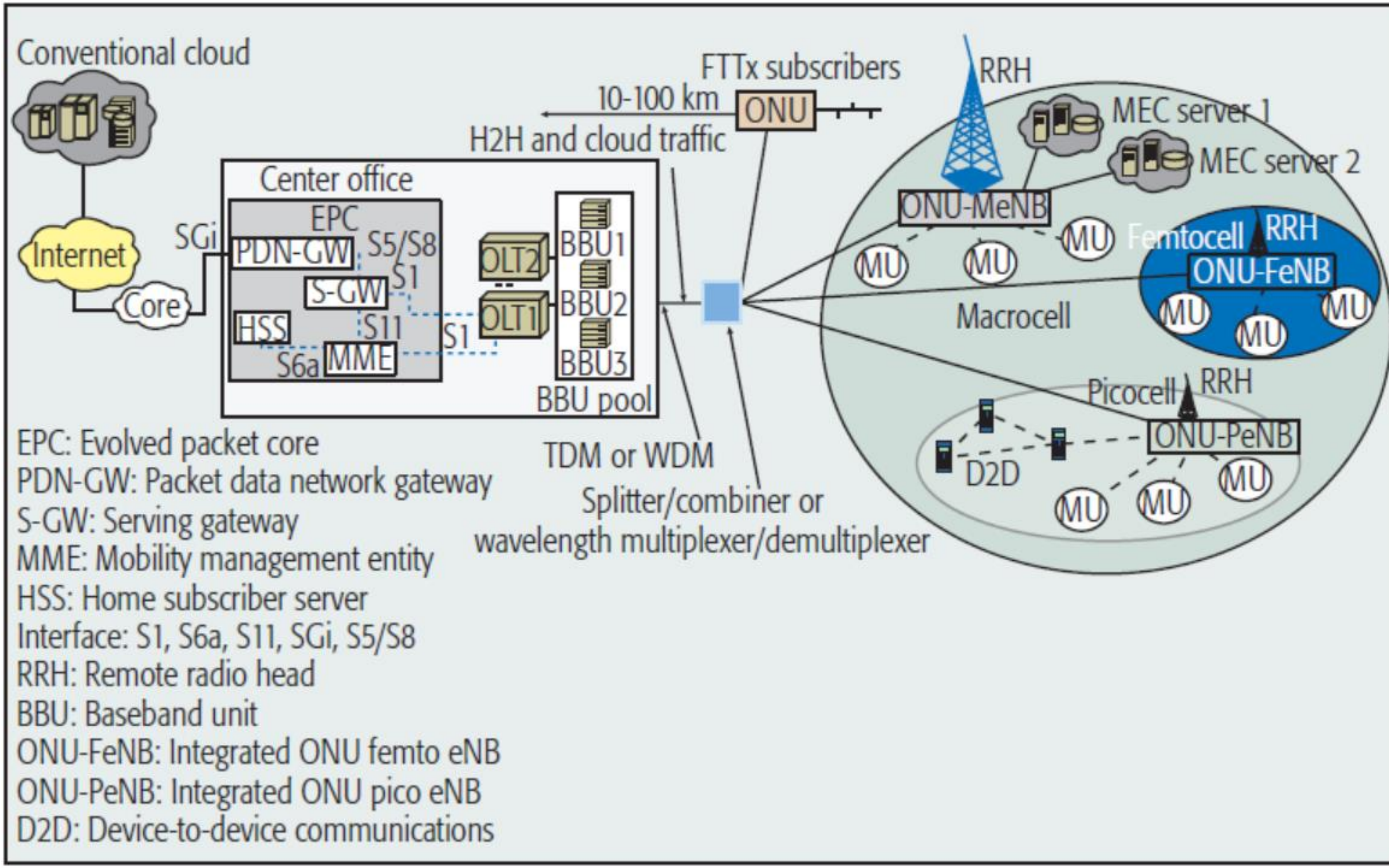
MEC over Ethernet-Based FiWi

- EPON or 10G-EPON in optical backhaul and wireless Ethernet LAN (WLAN) in front-end.
- backhaul has an OLT at central office, serves ONUs at customer sides.
- Set of ONUs at the premises of residential or business subscribers, providing FTTx service to wired subscribers.
- Set of ONUs is equipped with a mesh portal point (MPP) to interface with WiFi mesh network, consisting of mesh points (MPs) and mesh APs (MAPs), each serving mobile users they covered.
- MEC servers are connected to ONU-APs/MPPs through optical fiber point-to-point links.
- This design scenario is considered for medium and small-scale MEC applications, where each ONU-AP/MPP zone covers a small number of edge devices. It may be suitable for Tactile Internet applications and 5G-enabled robots.

MEC over 4G LTE-Based FiWi

- MEC servers are deployed at 4G LTE macro BSs (MeNBs)
- Bandwidth allocation is based on a pool/request/grant mechanism.
- OLT schedules transmissions and allocates bandwidth to each ONU-MeNB in a centralized fashion.
- Upon a granted bandwidth, each ONU-MeNB makes local decisions to schedule transmissions and allocate bandwidth to its associated edge devices and MEC servers in a fair and distributed manner.
- Depending on QoS requirements, an ONU-MeNB forwards packets to either OLT or local MEC server.
- MEC over 4G LTE-based FiWi networks are especially suitable for edge video orchestration, fast moving users (e.g., train passengers), and wide-area applications (e.g., smart cities).
- Further, it will significantly accelerate the deployment of V2R communications, where mobility and low latency are highly desirable.

MEC over FiWi networks: Case 3



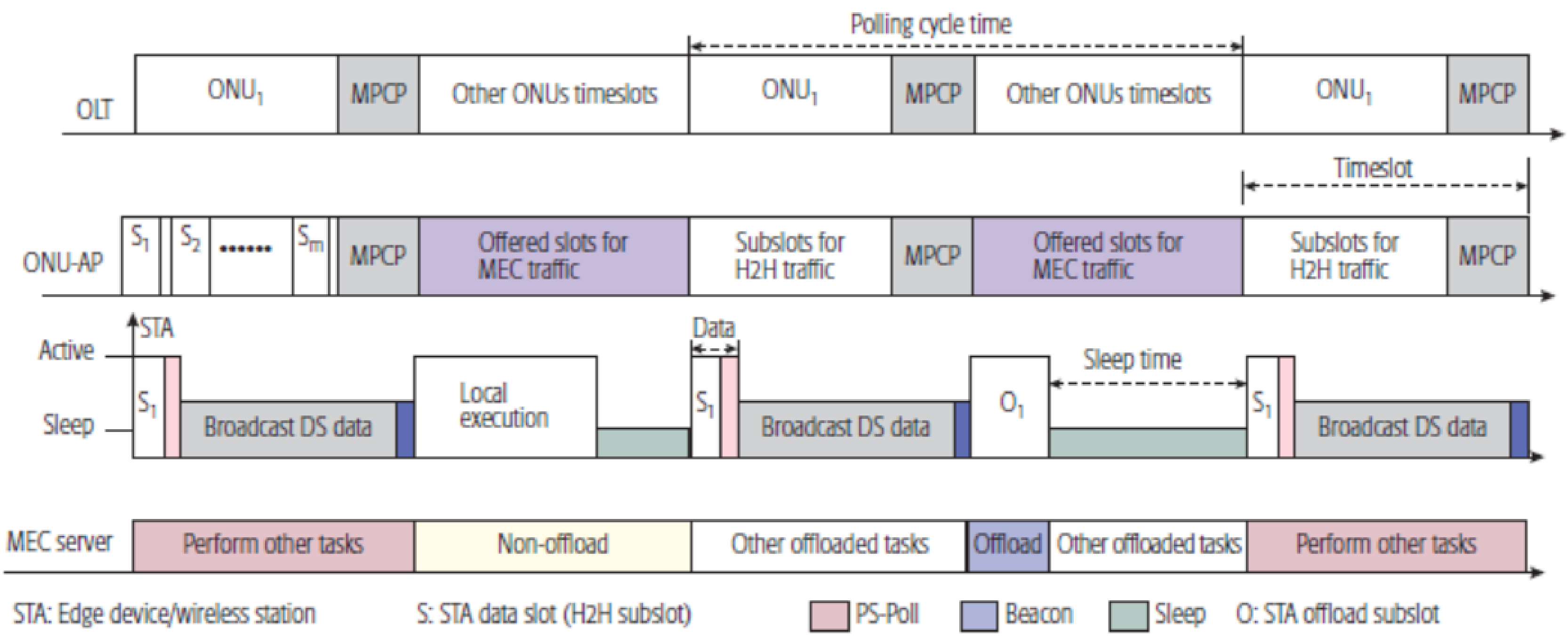
Coexistence of MEC and C-RAN in FiWi enhanced LTE-A HetNets

- C-RAN and cloudlet enhanced D-RAN may coexist in HetNets.
- WDM-PON may be deployed in this scenario without upgrading the optical infrastructure.
- C-RAN and cloudlet enhanced D-RAN may use different wavelength channels for baseband and RF transmission.
- WDM-PON provides a substantial reduction in the number of fibers used. The collocated ONU-FeNB (femtocell BS) and ONU-PeNB (picocell BS) may rely on WDM-based C-RAN, while an ONU-MeNB may rely on cloudlet enhanced D-RAN.
- Since MEC servers are connected to the ONU-MeNB, and the ONU-MeNB may rely on cloudlet enhanced D-RAN, the scheduling and bandwidth allocation should be handled by the ONU-MeNB.
- In the coordination of BBUs, the OLT is fully responsible for scheduling transmissions and allocating bandwidth to each ONUFeNB and NU-PeNB in a centralized fashion.

Coexistence of MEC and C-RAN in FiWi enhanced LTE-A HetNets

- However, due to not only the heterogeneity of constituting network components but also the presence of different radio access technologies in the same network, designing a unified resource management scheme is more complex than the previous two scenarios.
- Another possibility of deploying MEC over LTE-A HetNet is at the aggregation level. When multiple BSs are located close to each other, it is effective to deploy an MEC server there.
- Serving several BSs with a single MEC server not only centralizes computing resources but also reduces CAPEX/OPEX of network operators.
- Device-to-device (D2D) links may be employed between edge devices to improve spectrum efficiency and reduce backhaul traffic loads. Deploying MEC servers in LTE-A HetNets and at the aggregation levels pose several challenges. Among others, advanced resource management schemes are needed to jointly coordinate and synchronize a large number of BSs.

Resource Management



Resource Management Scheme

- Based on a two-layer time-division multiplexing (TDM).
- First layer is the optical backhaul, where OLT schedules time slots and allocates bandwidth to ONU-APs via multipoint control protocol (MPCP) messages (GATE and REPORT).
- In second layer, ONU-AP assigns bandwidth in subslots and schedules transmissions of both H2H and MEC traffic for its associated STAs.
- MEC offloaded traffic and computation results are scheduled outside the H2H subslots within an EPON polling cycle time (Fig. 4) to allow for H2H/MEC coexistence without degrading H2H network performance.
- ONU-AP receives offloaded traffic from its associated STAs. It then immediately relays the traffic to the MEC server using a dedicated point-to-point fiber communication link.
- When the ONU-AP receives the computation results from the MEC server, it broadcasts them to its STAs.

Resource Management Scheme (cont.)

- STA sends its H2H traffic to the ONU-AP within its assigned H2H subslots.
- ONU-AP allocates subslots to its STAs by means of WLAN Beacon and PS-Poll frames.
- These frames are extended by using their optional bits to include subslot parameters and bandwidth requests, respectively.
- ONU-AP broadcasts a Beacon to its STAs containing an uplink H2H subslot map, whereby each STA sends a PS-Poll at the end of its own H2H subslot.
- ONU-AP aggregates the requested bandwidth and reports it to the OLT via a REPORT at the end of its time slot.
- STA transmits offloaded traffic to and receives computation results from the MEC server in offload subslot.
- Sleep mode is scheduled for STA in a PON cycle if it is idle after the completion of both its H2H transmission and MEC offloading subslots.
- For network synchronization, the timestamp mechanism specified in the EPON standard is adopted, where all network devices assign their local clocks to the OLT global clock.

Summary

- MEC provides computing capability for Baseband Unite or Central Office
- MEC provides serving capability for user applications

- MEC is not tight coupled with Optical Networks

Thank you!

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