What Can MEC do for TDM PON based Mobile Fronthaul?

Wei Wang

BUPT Ph.d candidate & UC Davis visiting student
Email: weiw@bupt.edu.cn, waywang@ucdavis.edu

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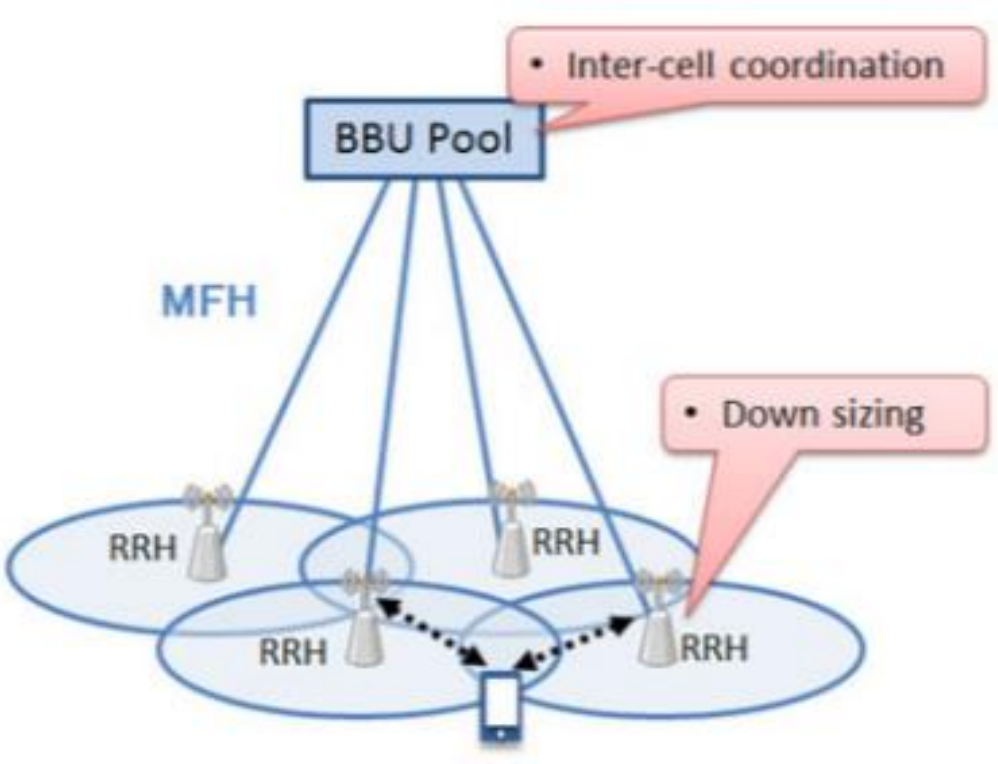
What is Mobile Fronthaul?

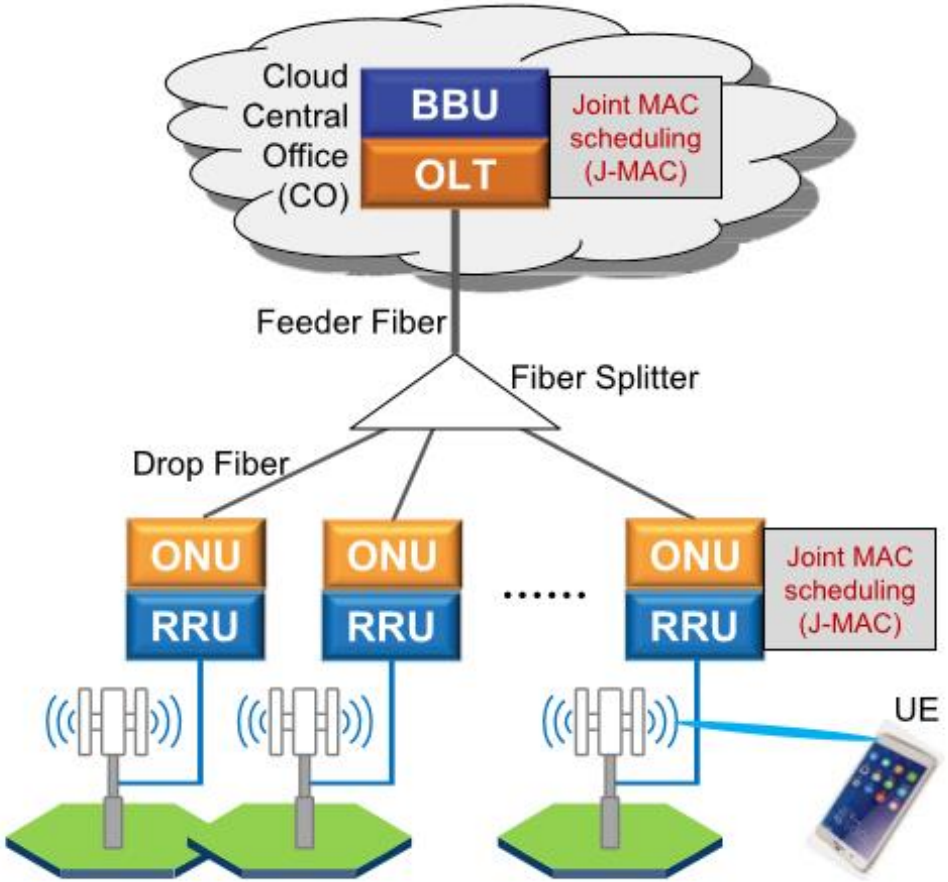
- Mobile Base-Station=Base Band Unit (BBU) + Radio Head (RH)
- Cloud-RAN(C-RAN): Centralized BBU pool + Remote Radio Heads (RRHs)
- RRH is the antennas sites with only RH functions
- Benefits offered by C-RAN: 1) inter-cell coordination, 2) down-sizing of antennas
- Mobile Fronthaul (MFH): intra-base station transport, used to connect BBU and RRH.



J. i. Kani, J. Terada, K. I. Suzuki and A. Otaka, "Solutions for Future Mobile Fronthaul and Access-Network Convergence," in *Journal of Lightwave Technology*, vol. 35, no. 3, pp. 527-534, Feb.1, 1 2017.

TDM-PON for Fronthaul

- Why PON? (1) one to multi-point architecture; (2) cost-efficient; (3) reuse existing fibers
- https://www.nokia.com/en_int/news/releases/2017/06/20/nokia-bell-labs-first-to-show-use-of-ultra-low-latency-10g-pon-for-mobile-fronthaul
- Dynamic Bandwidth Assignment (DBA) in TDM-PON systems.
- Optical Line Terminal (OLT) assigns bandwidth grants to each Optical Network Unit (ONU) according to bandwidth requests from ONUs.
- Issue:
- The assignment procedures result in a delay of around 1 ms, which may exceed the latency threshold of 5G wireless communications.



Latency in TDM-PON

- With conventional DBA

- Control message latency
- 1) propagation latency of REPORT message
- 2) grant processing time
- 3) propagation latency of GATE message

- Data latency
- 4) propagation latency of data (distance)
- 5) transmission latency of data (b/w)

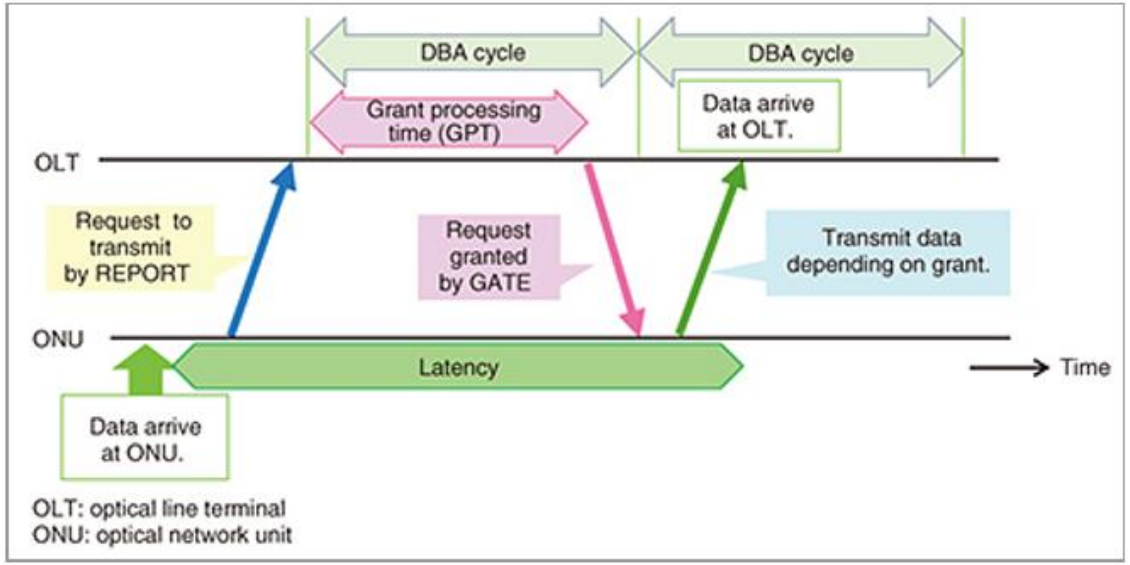
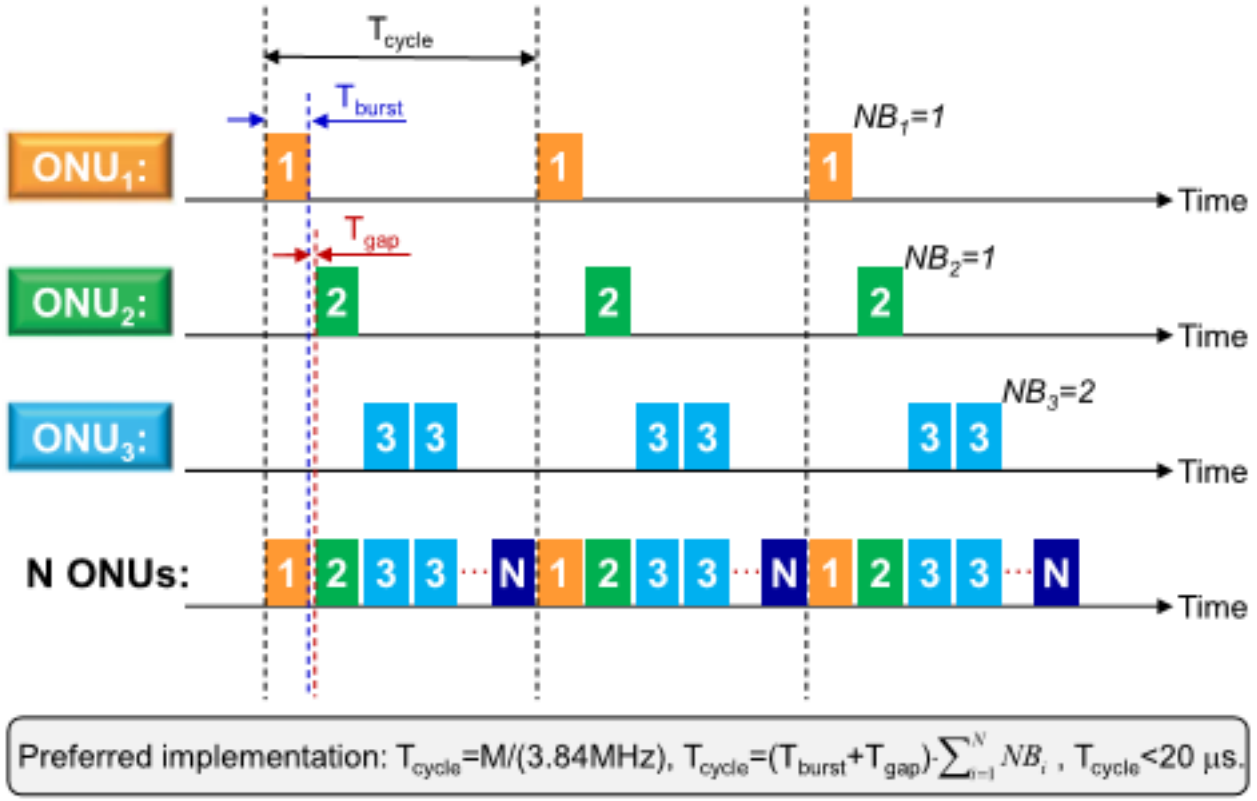


Fig. 2. Message exchange between ONU and OLT in SR-DBA.

Solutions for low latency TDM-PON

- Solution A: (Fixed scheduling)
- Accelerated burst scheduling of PON
- T_{cycle} : time for OLT to scan through all ONUs once (20μs preferred)
- T_{burst} : predetermined burst period for ONUs to transmit CPRI frames
- T_{gap} : to avoid implementation of imperfection-induced burst collision

- Flexible bandwidth allocation can be realized by assigning each ONU a given number of bursts per cycle



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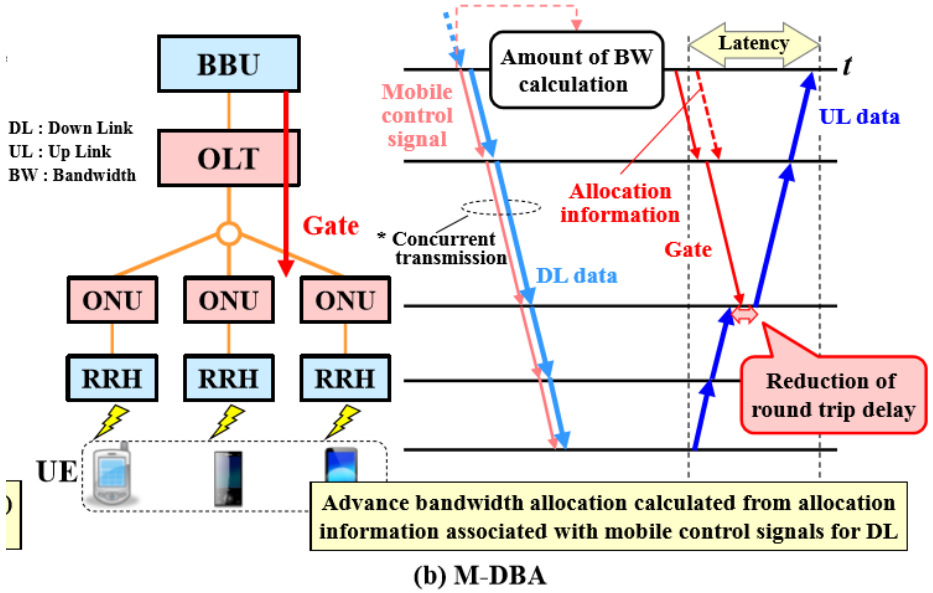
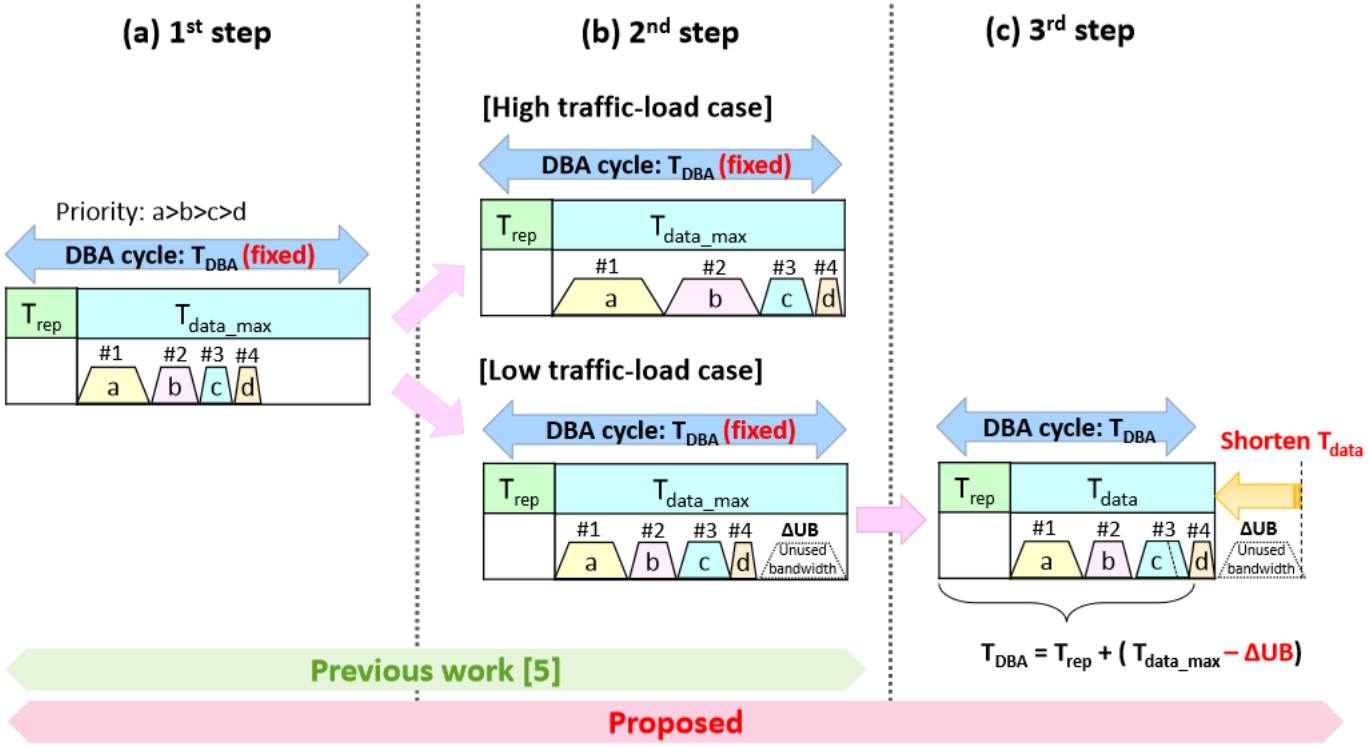
Solutions for low latency TDM-PON

- Solution B: (Advanced Scheduling)
- Request Bandwidth(RB)
- Guaranteed Bandwidth(GB)
- Unused Bandwidth(EB)



(b) M-DBA

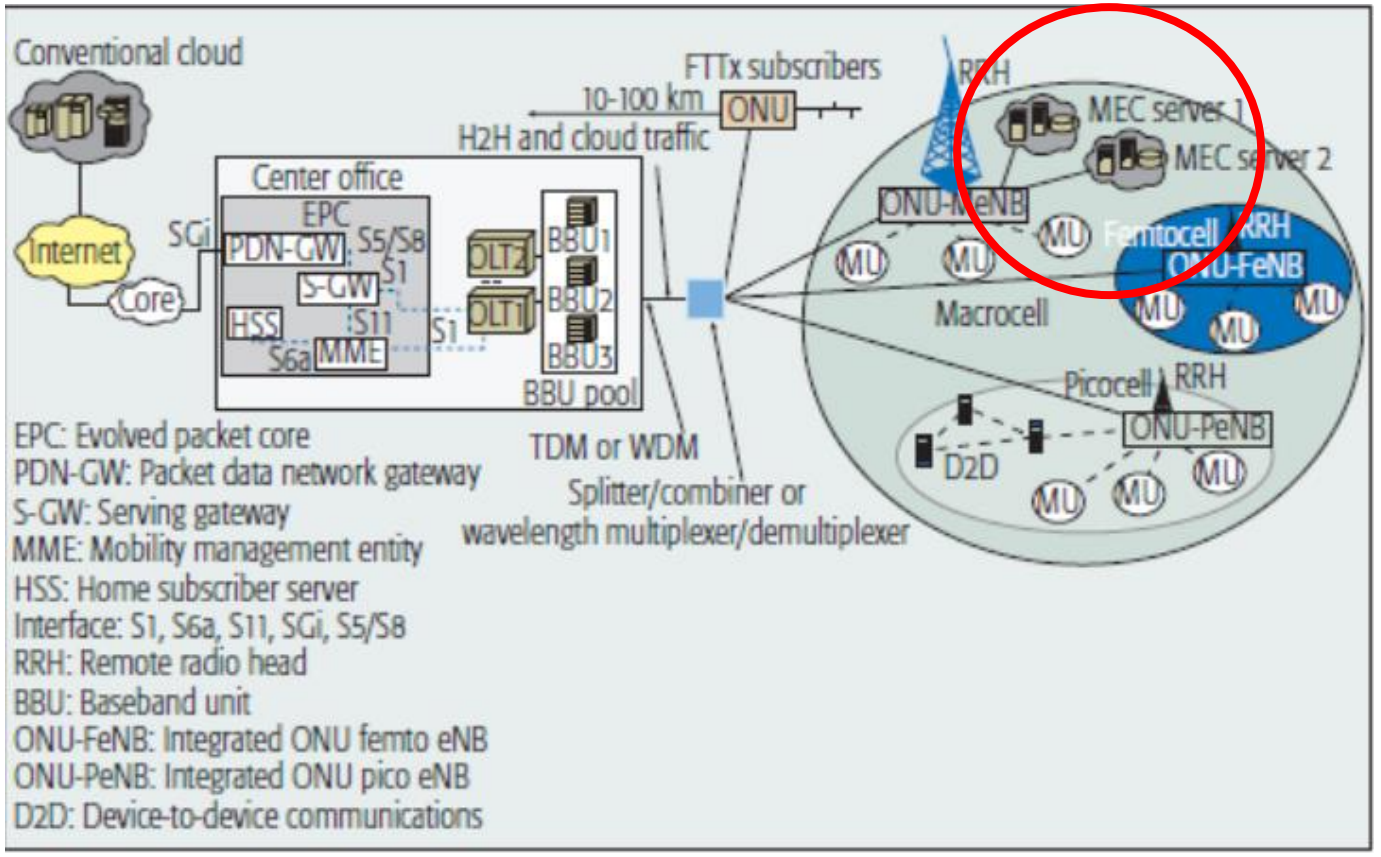


Where should MEC locate at in Fronthaul?

- MEC in PON-based Fronthaul

- MEC at ONU side?
- According to CPRI or other BBU-RRU split options, high layer(IP or above) protocols are not supported at ONU side.

- The most possible option is to deploy MEC servers at OLT (BBU) side



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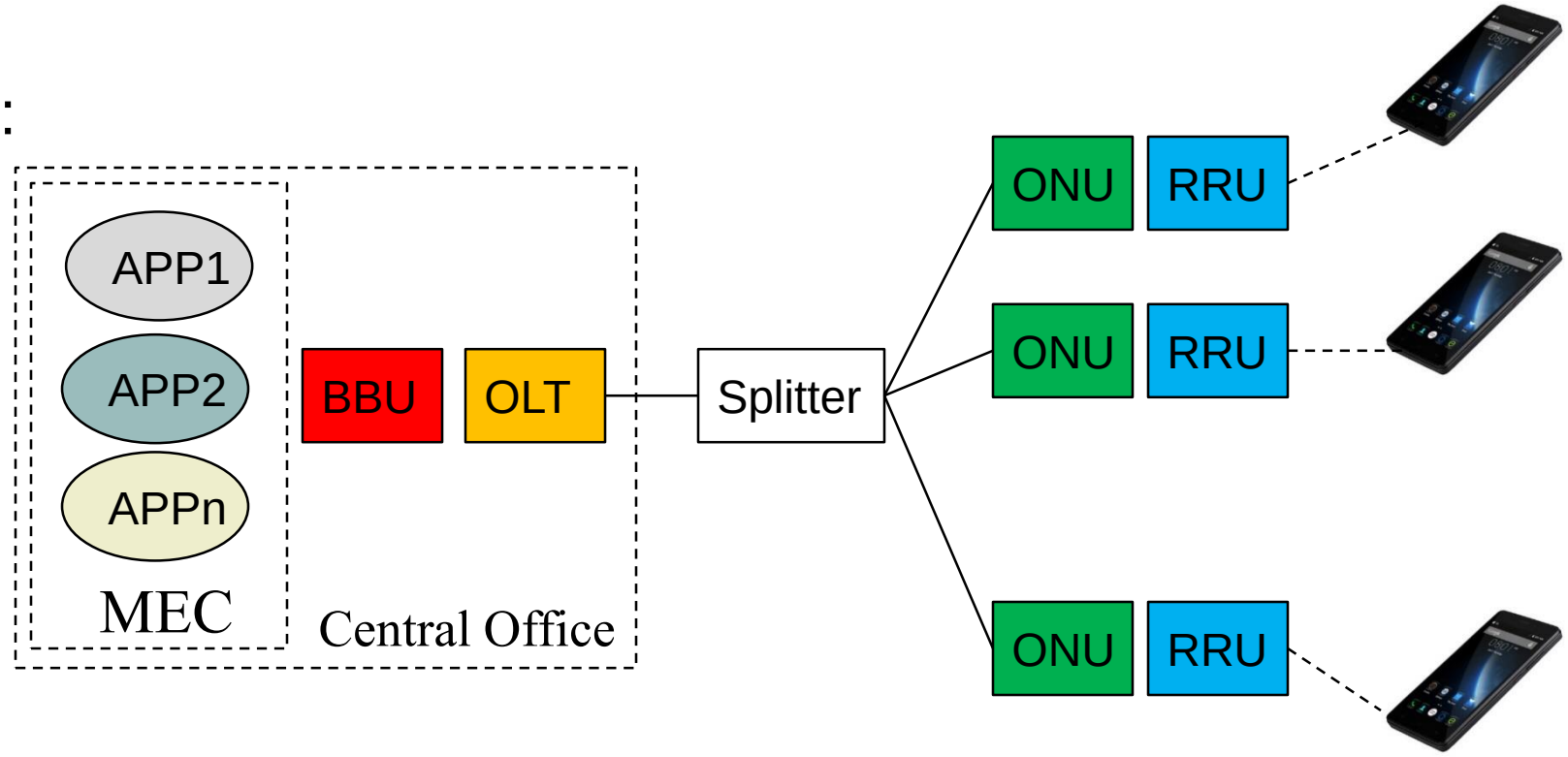
E2E Latency for MEC+PON based APPs

E2E latency components:

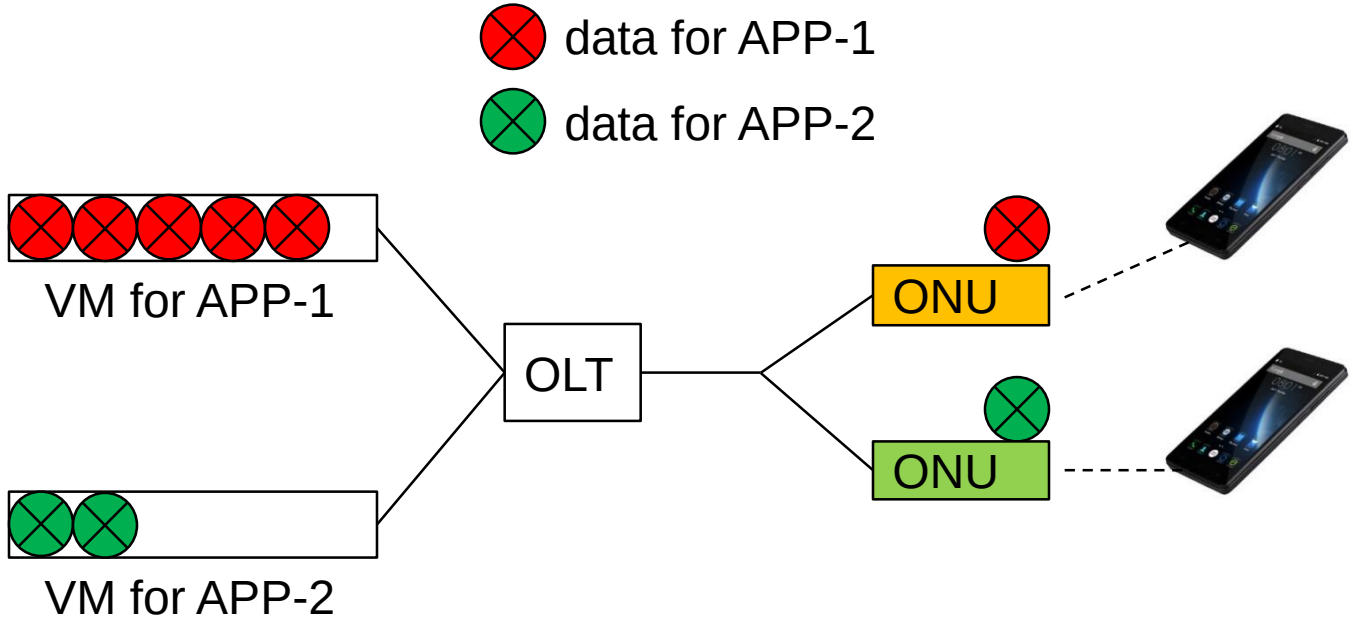
- Propagation (constant)
- Queuing at ONU (DBA)
- Transmission at ONU (DBA)
- Processing at VM (Workload Assignment)
- Queuing at VM (Workload Assignment)



Coordinated MEC+PON scheduling

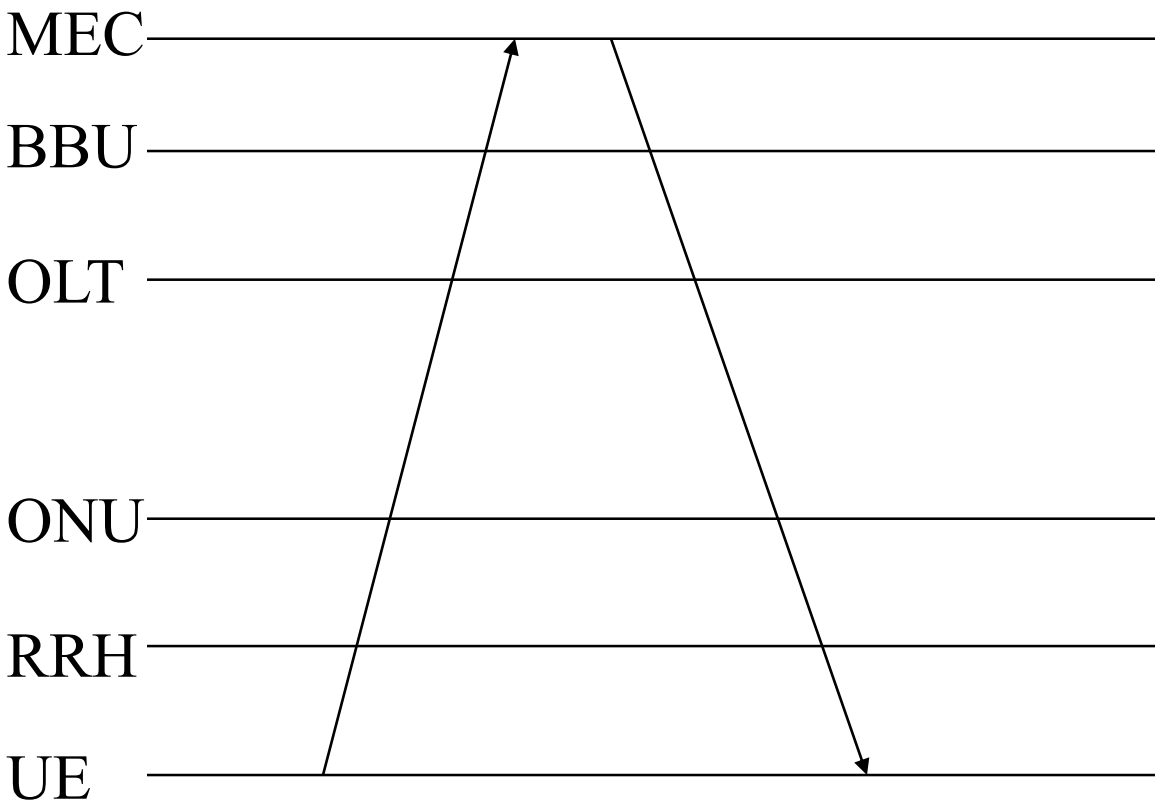
- Motivation
- Which data go first?

- Case 1: data for APP-1 go first, and data for APP-2 experience a certain of queuing latency in ONU, but data for APP-1 still need to wait at VM.
- Case 2: data for APP-2 go first, and data for APP-1 experience a certain of queuing latency in ONU, but the queue in VM for APP-1 gets shorter when it arrives.



How to coordinate PON with MEC?

- 1. coordinated decision should be made at BBU(OLT) side.
- 2. what information can be used for coordination?
- 2.1. APP information at UE
- 2.2. B/W demand at ONU
- 2.3. TDM channel utilization at OLT
- 2.4. MEC utilization at MEC server



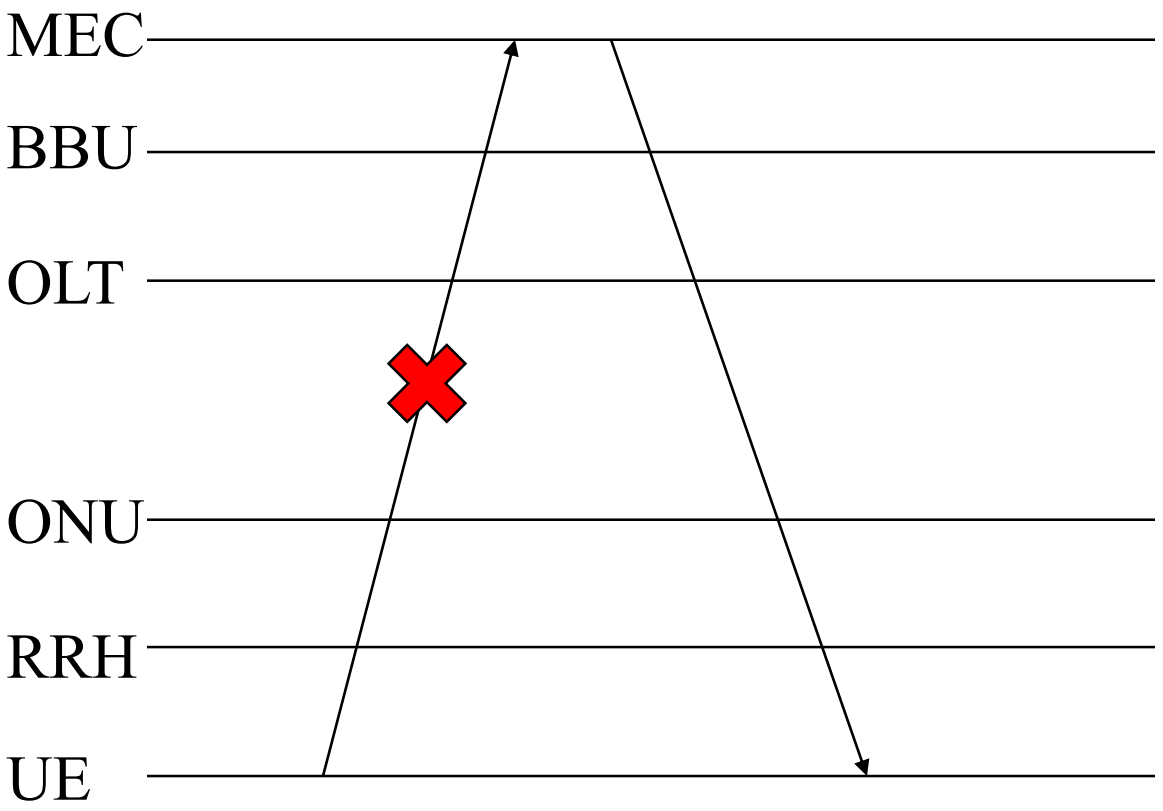
How to coordinate PON with MEC?

- How to use ONU and UE information at OLT(BBU)?
- Upstream report? NO!

Upstream channel is not reliable and data may experience latency. Thus, report information may not be effective when it arrives to OLT.

So, what we can use to make coordinated decisions is

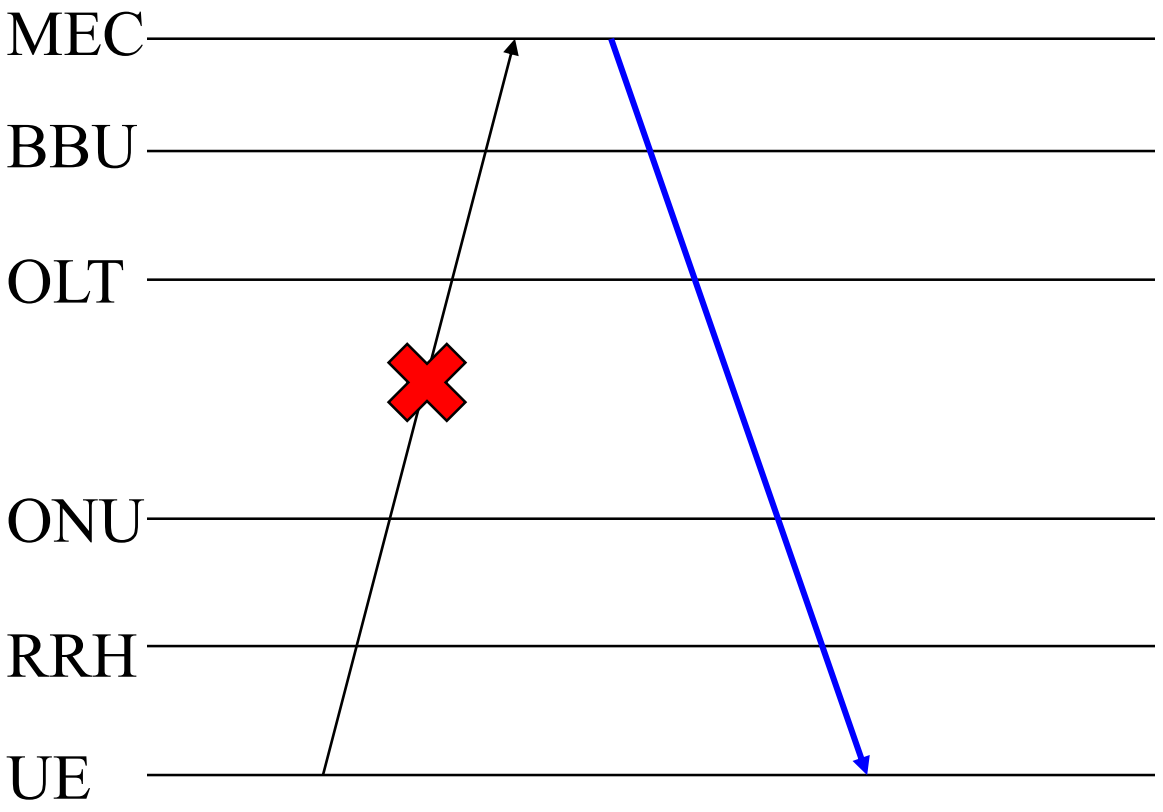
- TDM channel utilization at OLT
- MEC utilization at MEC server



How to coordinate PON with MEC?

- 1. what can we control?
- 1.1. transmission order of ONUs(DBA)
- 1.2. bandwidth(time slots) for each ONU (DBA)
- 1.3. some behaviors of UE
- 1.4. workload scheduling at MEC server

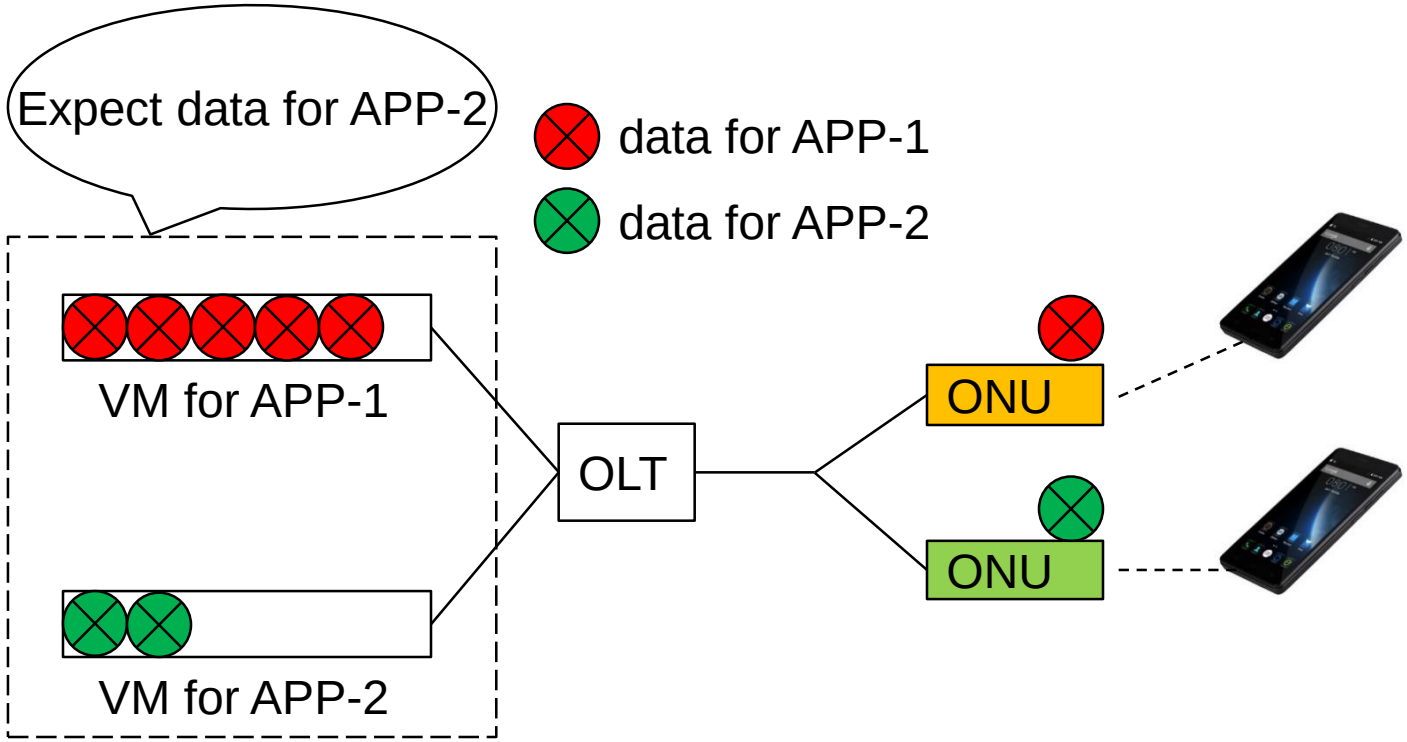
- 2. How to control ONU and UE?
- Downstream channel.



How to coordinate PON with MEC?

- How to coordinate ONU with MEC
- B/W for each ONU
- Transmission order of each ONU

- In the right example,
- We have no control of data at APP layer by adjusting B/W or transmission order of ONU
- ONU works at MAC or PHY layer, according to split point in Fronthaul. Not aware of APP

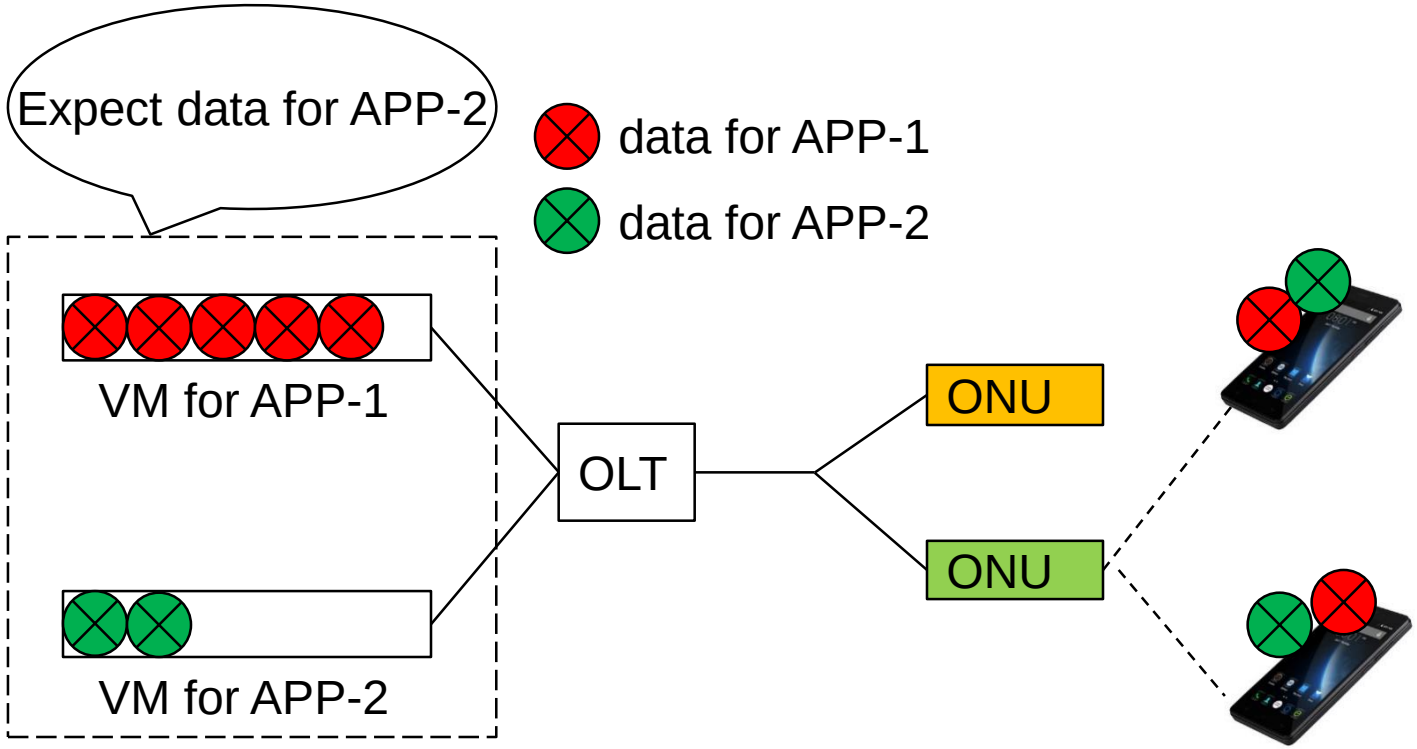


How to coordinate PON with MEC?

- How to coordinate UE with MEC?

- Inside each UE, order of output data of different APPs.
- Among multiple UEs, order of transmission to a same ONU.

- However, BBU(OLT) has no information about which APP is generating data in UEs.



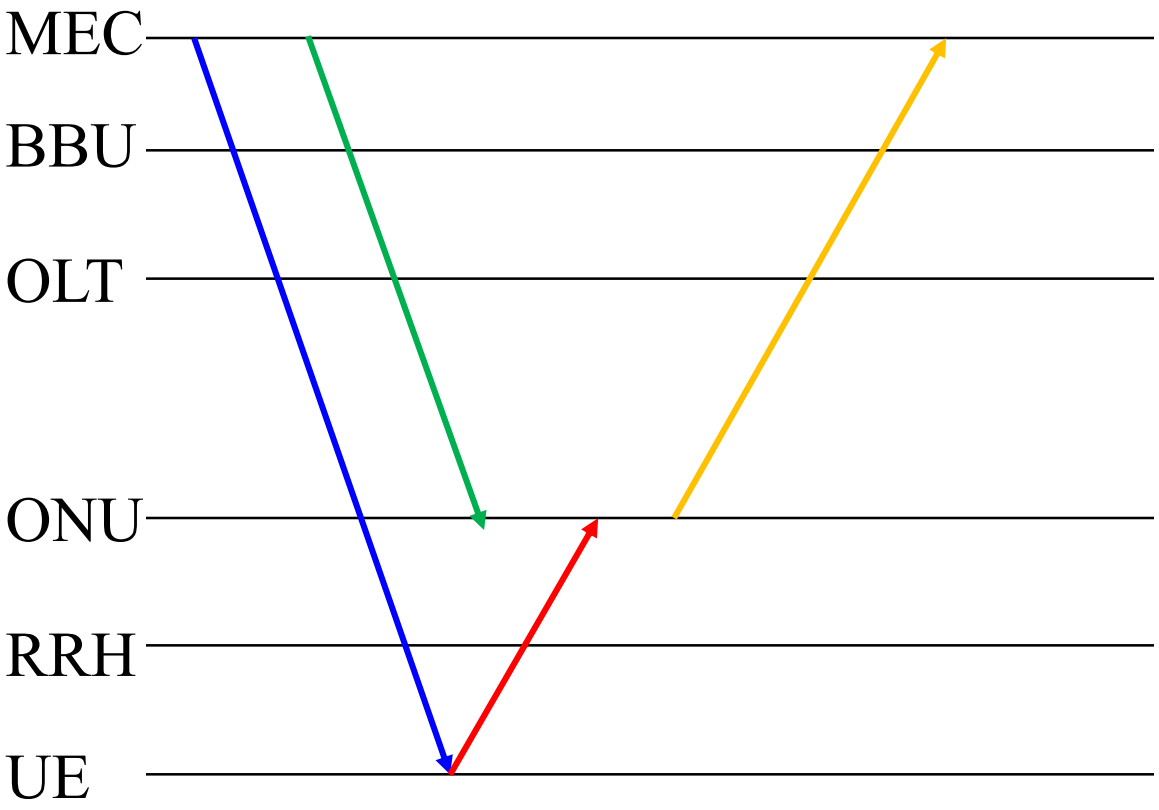
Workflows of coordinated scheduling

- MEC->UE:
- Hey UEs, output data in order of APP a, b, c

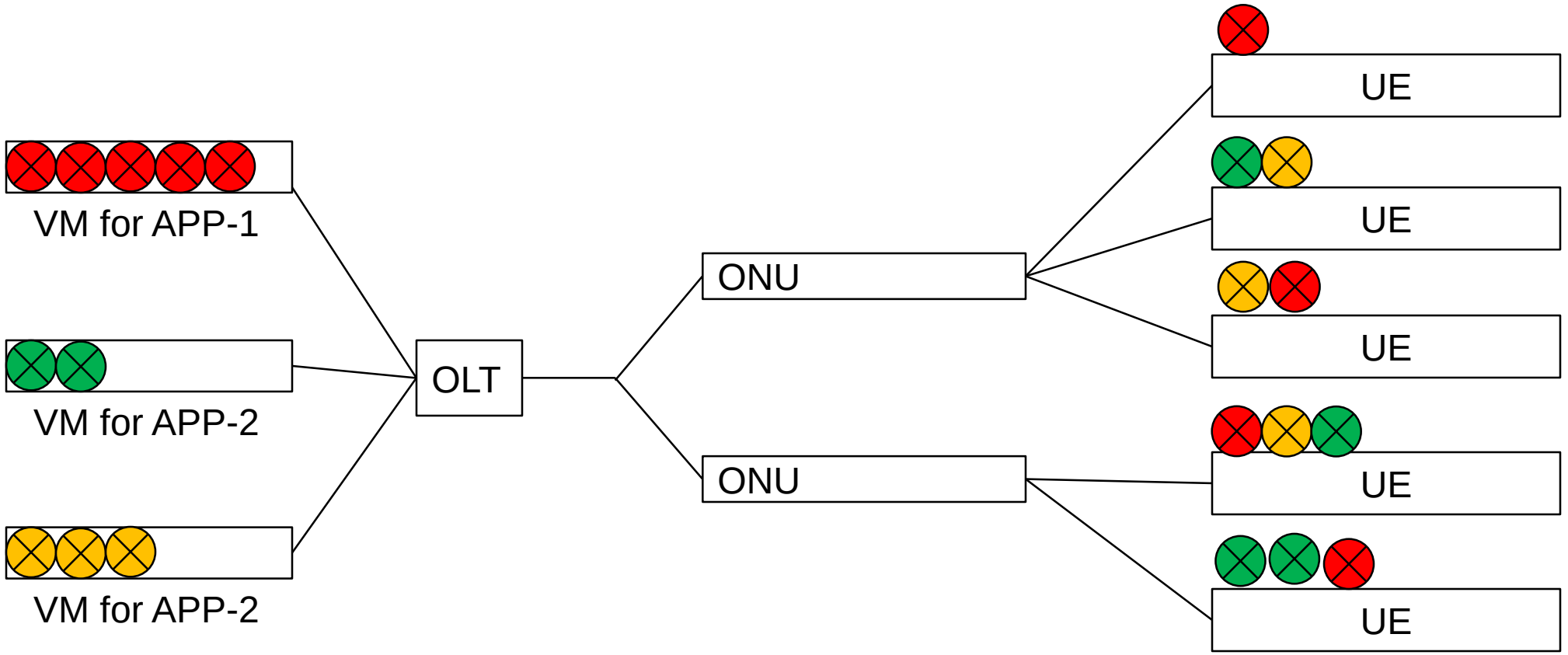
- MEC->ONU:
- You will have XX time window to transmit data after yy seconds.

- UE->ONU:
- Buffering data in order of APP a, b, c

- ONU->OLT->MEC:
- Transmitting data to OLT then to MEC



Overview of coordinated scheduling



Problems in coordinated scheduling

- However,
- Data generated by different APPs at UE may not match the order what we expect.
- Data amount at ONU may not match the allocated B/W.

- For above mis-expectation, we can measure,
- Amount of data received for each APP.
- Latency experienced in networks.

- According to the measured mis-expectation
- We do further adjustment on scheduling

Problem Definition

- Input:
- MEC queueing information of each APP
- Measured latency of data coming from each ONU
- Measured amount of data from each APP

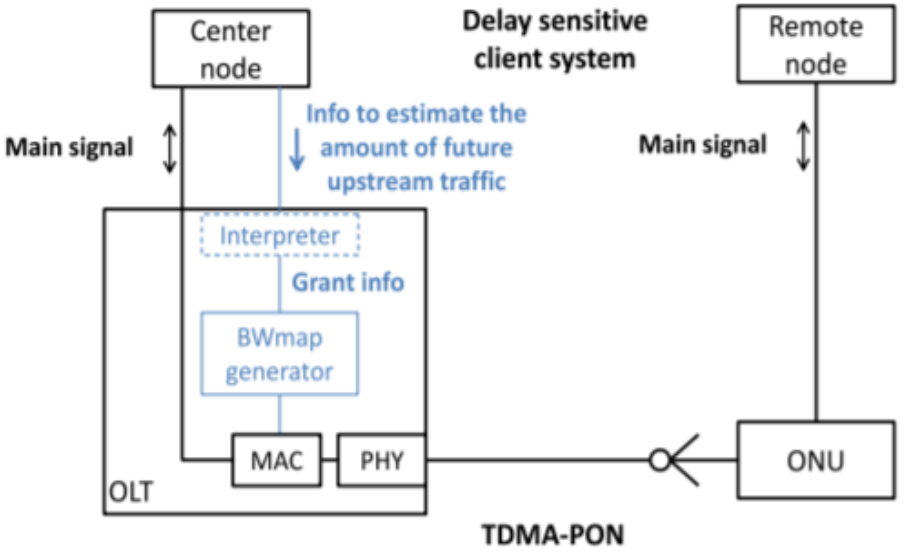
- Decide:
- How does each UE order their output for each APP.
- Transmission order of each ONU.
- Time window for each ONU.

- Objective
- Optimize E2E latency for each APP.

Machine Leaning for coordinated scheduling

- Use ML to do more accurate expectations.

- Delay-sensitive client system comprises Center node (BBU) and Remote node(RRH)
- It is assumed that BBU has information to estimate the amount of future upstream traffic from each ONU.
- The OLT implements an interface to receive this information from BBU to make accurate assignment in advance to the arrival of the traffic
- Minimizes delay in the TDMA-PON DBA section as well as the mis-assignment



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Thank you!

Wei Wang