

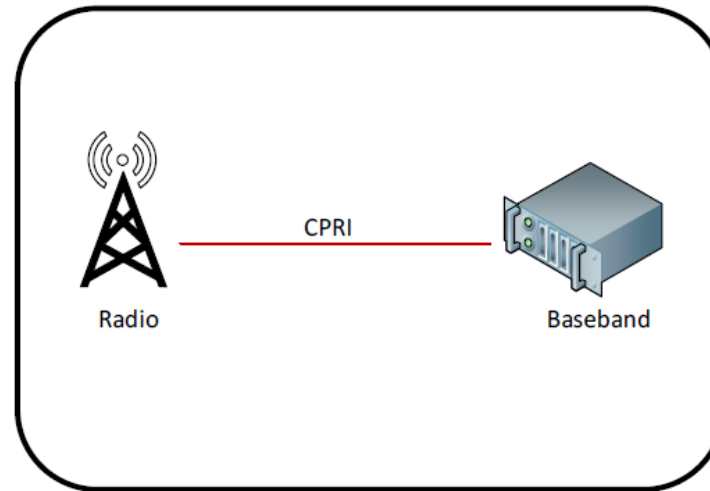


# Baseband Function Placement in Ethernet-based 5G Fronthaul Networks

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# Background

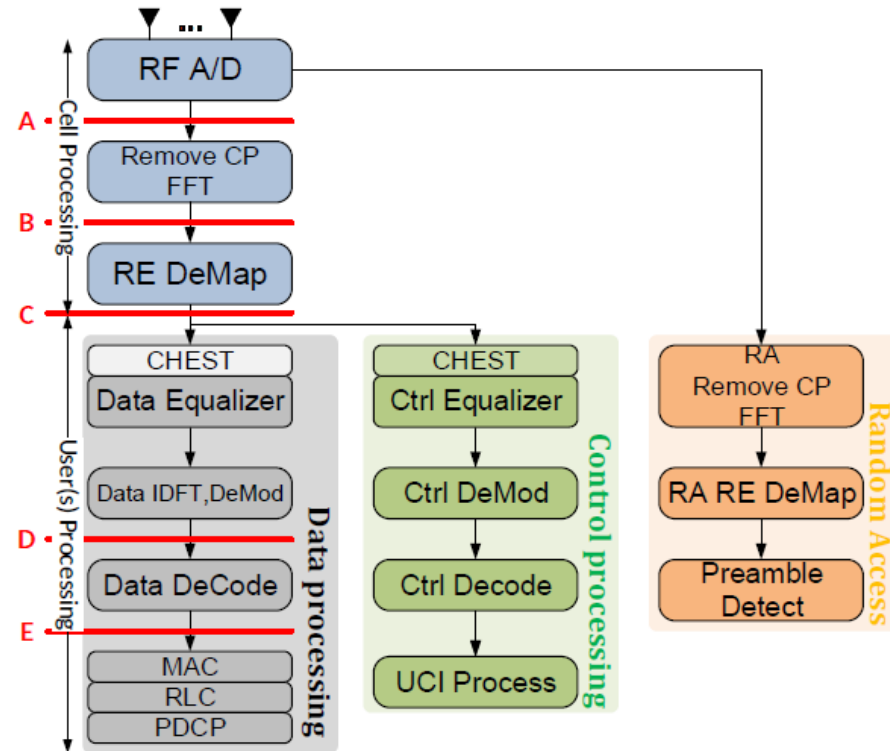
- ❑ In C-RAN, radio signals are first digitized at the antenna sites by **remote radio heads (RRHs)**, and then transported via **fronthaul network** to centralized **baseband processing units (BBUs)** for signal processing.
- ❑ However, the major challenge is the **huge bandwidth requirement** for fronthaul network.



X. Liu, *et al.*, "Evolution of mobile fronthaul towards 5G wireless and its impact on time-sensitive optical networking," *Proc. OFC*, 2017.

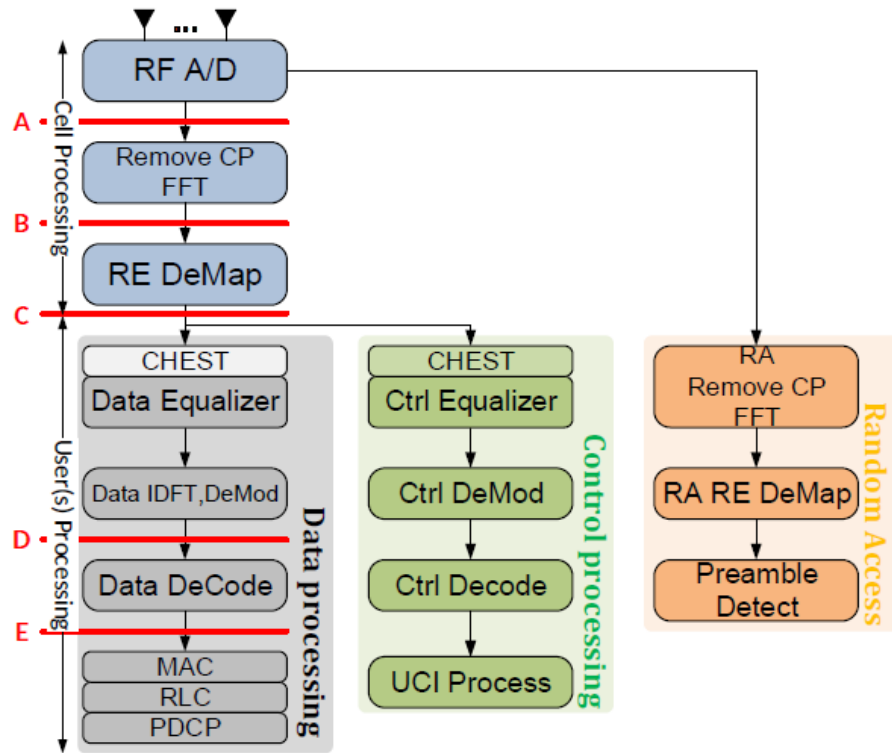
# Background

- ❑ Functional split pushes BBU functions to RRH, thus reducing fronthaul bandwidth requirement.



Entire BBU stack

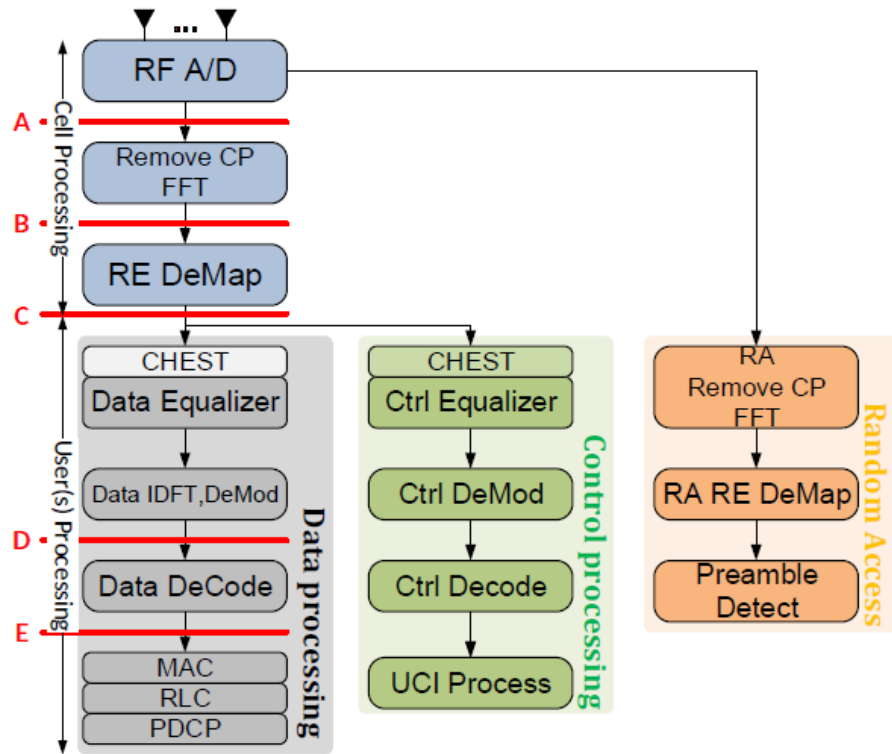
# Background



Entire BBU stack

- ❖ **Split A:** RRH includes only time-domain RF and A/D functions while BBU includes all other functions. This is the standard split considered in C-RAN.
- ❖ **Split B:** RRH further removes the cyclic prefix (CP) in the time domain. It then applies FFT, transforms samples from time domain to frequency domain, and finally removes guard band sub-carriers.
- ❖ **Split C:** RRH Includes also the resource element demapper, which categorizes used resources based on pre-allocated information of each served user.

# Background

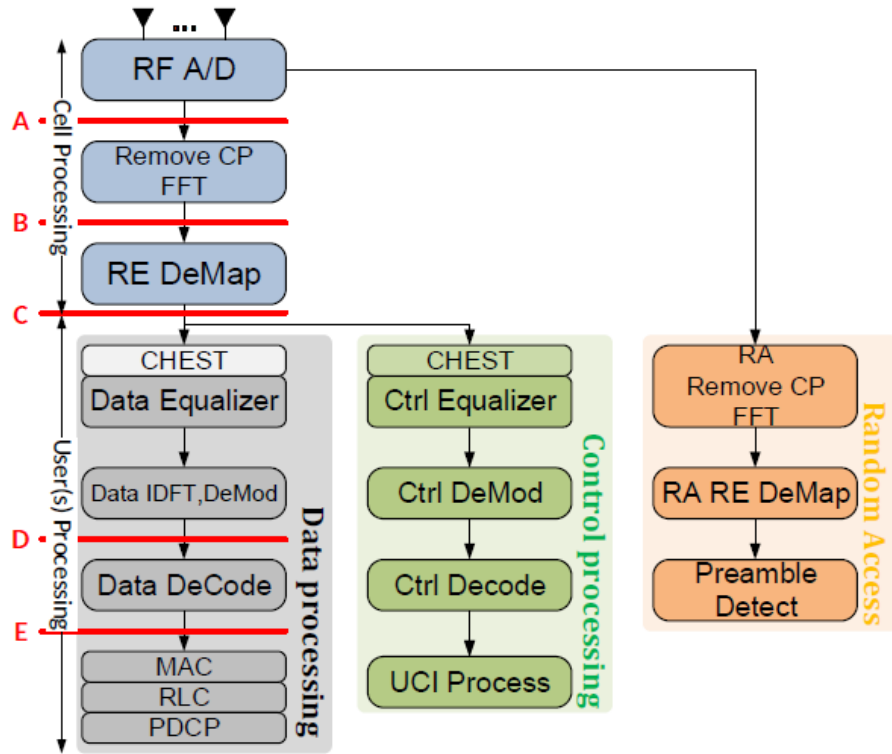


Entire BBU stack

- ❖ **Split D:** RRH now is also in charge of some per-user processing. Channel estimation based on control and data reference signal (RS) symbols is performed and the estimation result is then applied for equalization. Afterwards, signal for each user goes through IFFT and demodulation module to output user data in time domain.
- ❖ **Split E:** RRH further performs bit-rate processing, including de-scrambling, de-rate matching, channel decoding and CRC check. BBU will receive decoded user data in bits for higher layer processing.

# Background

## ❑ Bandwidth requirement reduction



Entire BBU stack

Scenario	1	2	3
Bandwidth	20 MHz		
Oversampling Ratio	1		
Rx Antennas	4		
Cyclic prefix length	Normal		
MIMO	4 Layer		
PUCCH RB	4		
SRS BW Config	7		
SRS SF Config	9		
Control Overhead	4.3%		
RA Config	0		
RA Overhead	0.3%		
Modulation	64 QAM	16 QAM	QPSK
TBS index	26	16	9
Time sample bitwidth	16		
Frequency sample bitwidth	16		
LLR bitwidth	8		

Scenario	1	2	3
Split A	3.93 Gbps 5 RRHs		
Split B	2.15 Gbps 9 RRHs		
Split C	2.14 Gbps 9 RRHs		
Split D	2.63 Gbps 7 RRHs	1.76 Gbps 11 RRHs	878.3 Mbps 22 RRHs
Split E	300.8 Mbps 66 RRHs	123.9, Mbps 161 RRHs	63.7 Mbps 313 RRHs

# Background

## ❑ Cost issues with functional split:

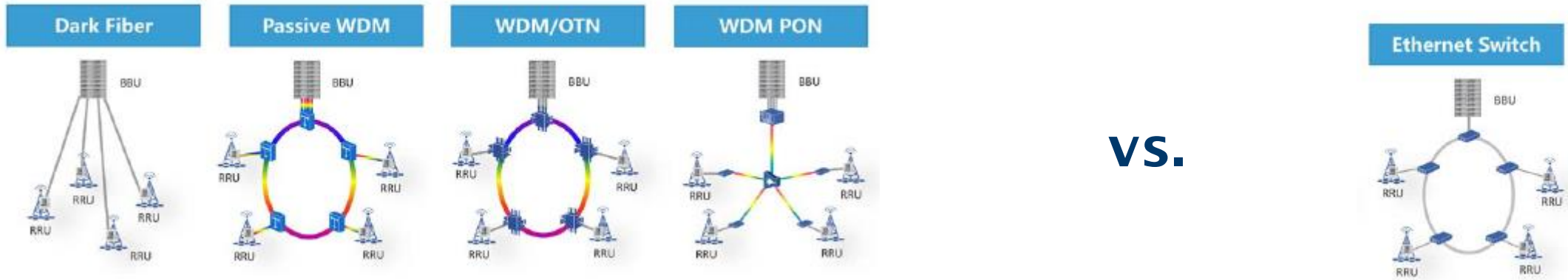
- (1) Pushing too many BBU functions to RRH increases cost tremendously.
- (2) The number of RRHs (small cells) grows fast, resulting in a large multiplier for single-RRH functional-split cost.

## ❑ Remedies:

- ❖ For (1), push only cell-level BBU functions to RRH (Doing so also benefits coordinated signal processing and advanced interference avoidance schemes).
- ❖ For (2), make BBU functions sharable among multiple RRHs.

# Background

## ❑ Cost issues with fronthaul networks:

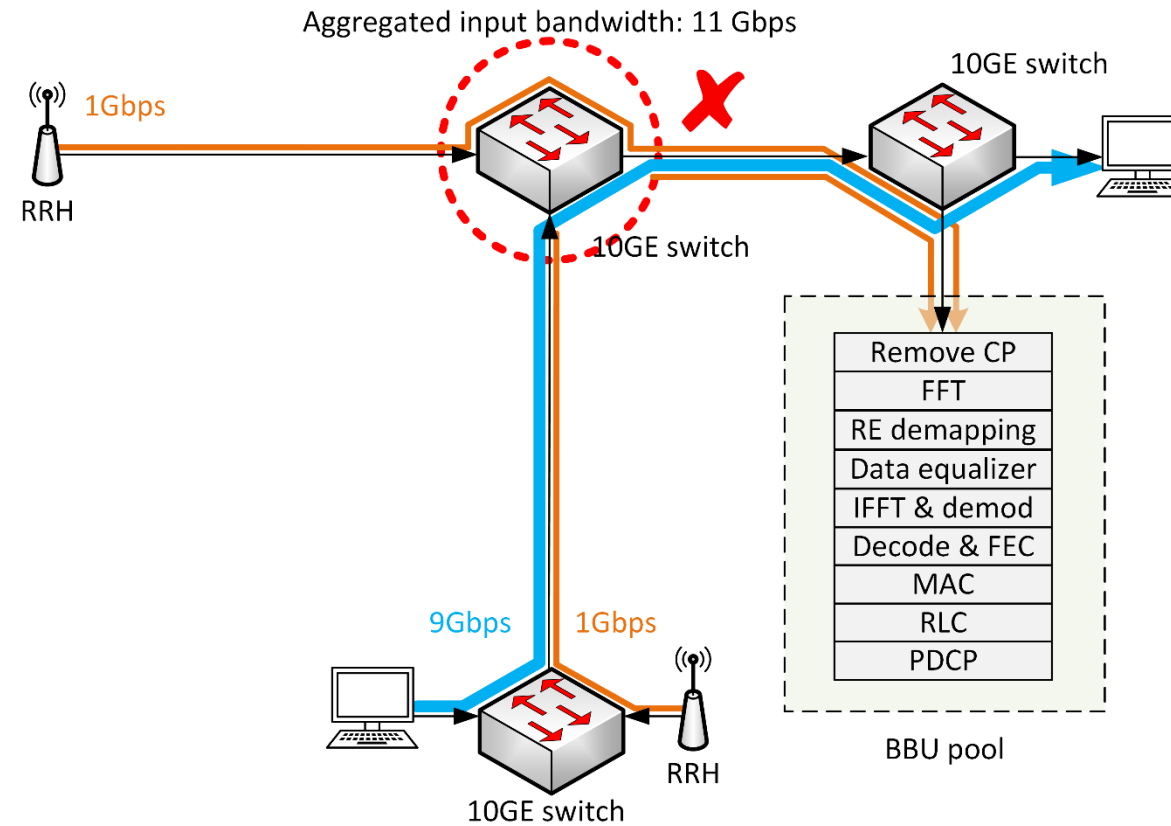


- ❖ Ethernet equipment is cheap.
- ❖ Ethernet is a widely adopted and nearly ubiquitous standard technology.
- ❖ Existing Ethernet networks can be directly used to transmit fronthaul traffic, **as long as traffic (other than fronthaul traffic, referred to as background traffic hereafter) carried on existing Ethernet networks is light.**



# Problem

- What if background traffic carried by existing Ethernet network is heavy?

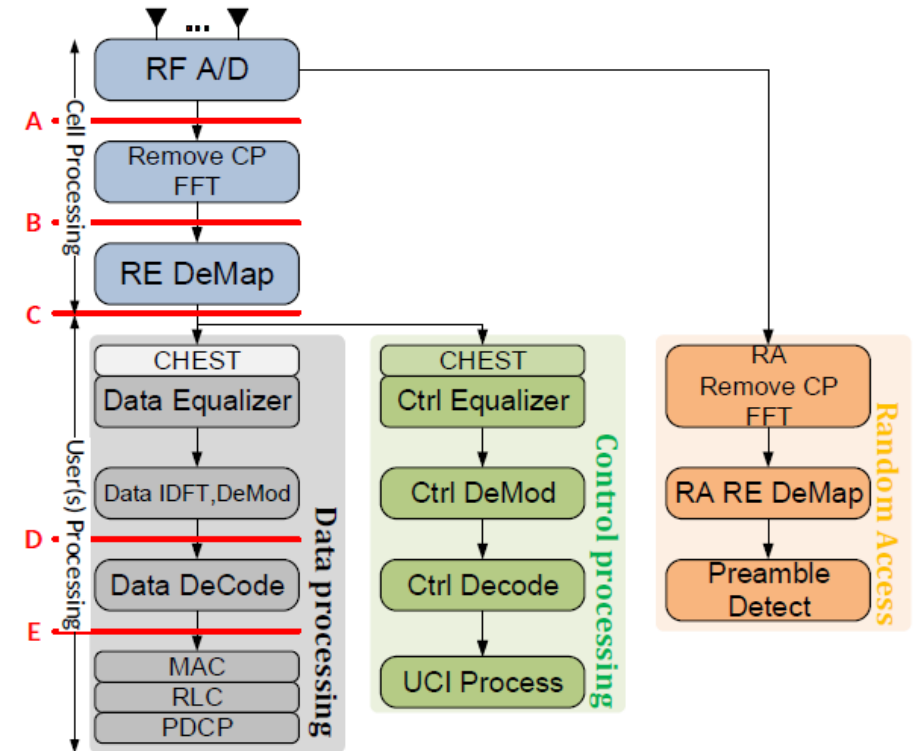
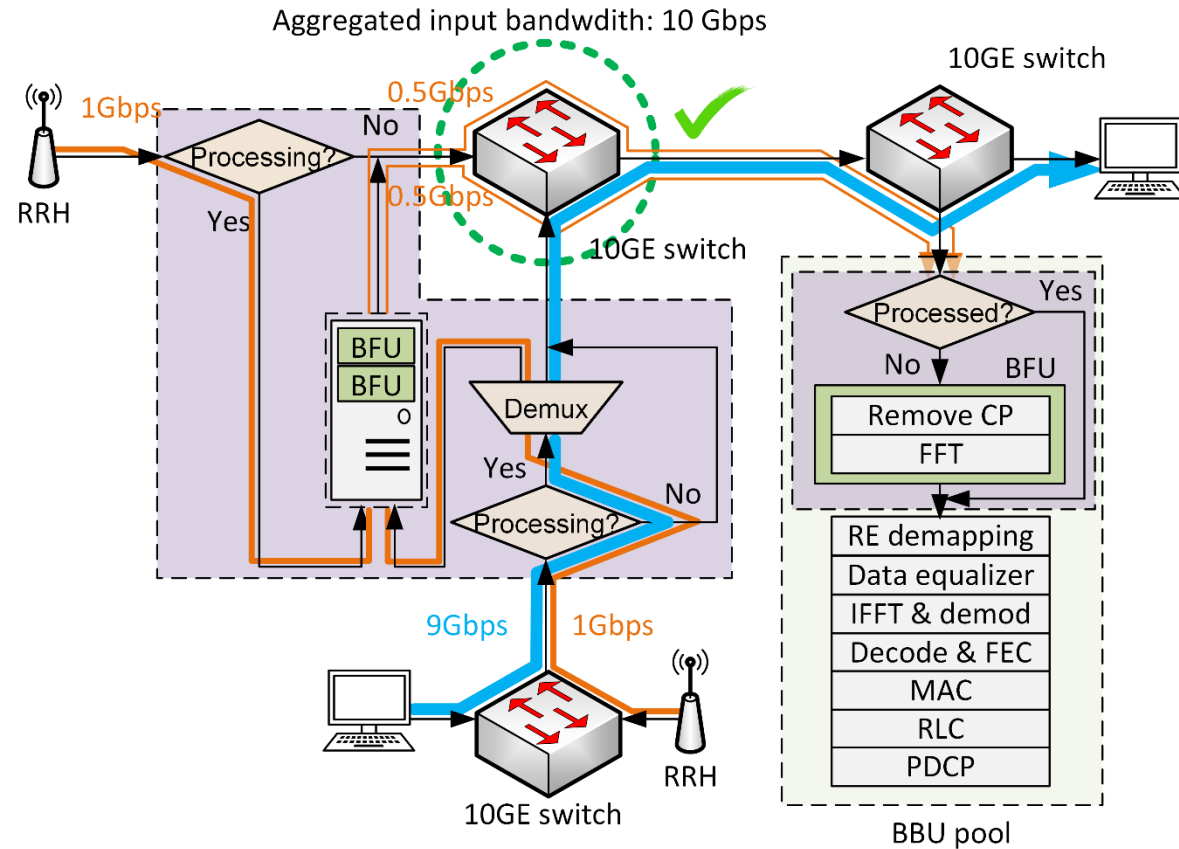


# Problem



- ❑ Under the scenario where background traffic is heavy, we still want to utilize existing Ethernet network to carry fronthaul traffic to **reduce network cost**.
- ❑ Solution:
  - ❑ Use functional split to reduce fronthaul bandwidth requirement.
  - ❑ In the meantime, recall from previous slide that we want functional split to be: (1) sharable and (2) at cell level to **reduce functional split cost**.

# Solution



# Problem Statement

## □ Given:

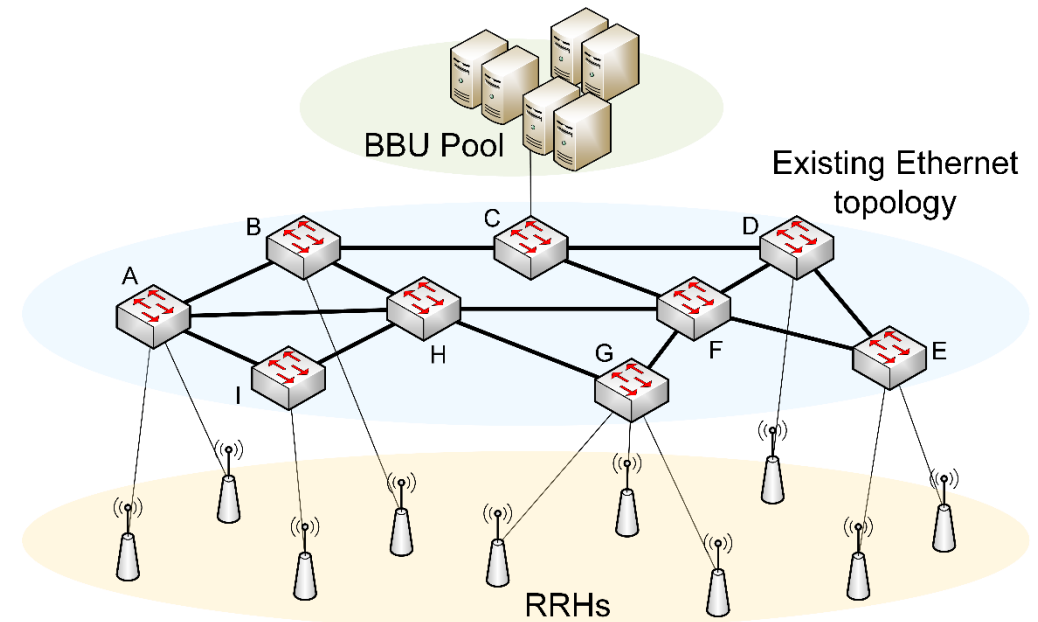
- ❖ Ethernet network topology and its connections to BBU pool and RRHs.
- ❖ Ethernet Background traffic.

## □ Objective:

- ❖ Minimize cost in terms of # of BFUs to accommodate fronthaul traffic from RRHs.

## □ Constraint:

- ❖ Latency:
  - ❖ Transmission delay
  - ❖ Propagation delay
  - ❖ Queuing delay
  - ❖ BFU processing delay





**Thank you!**