

# Deterministic Scheduling of Periodic Messages for Cloud RAN

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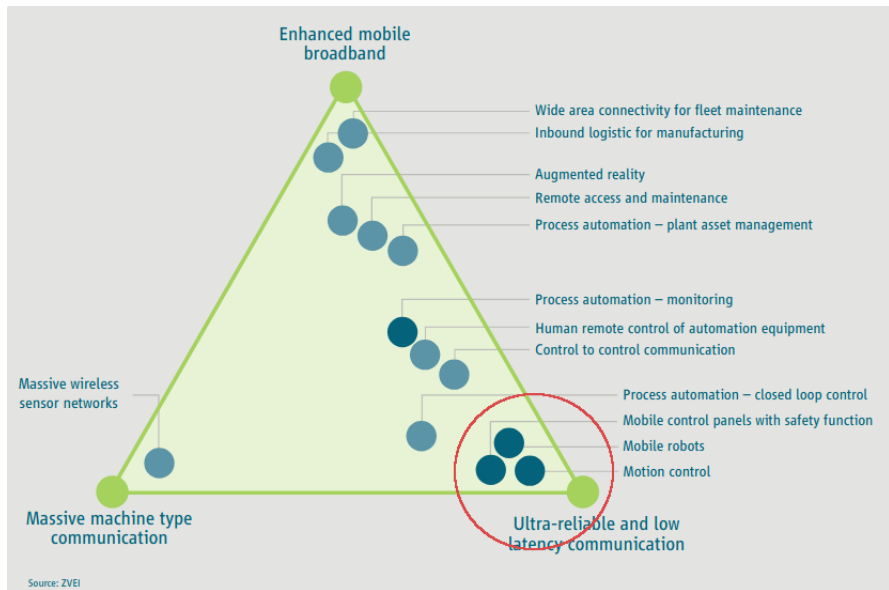
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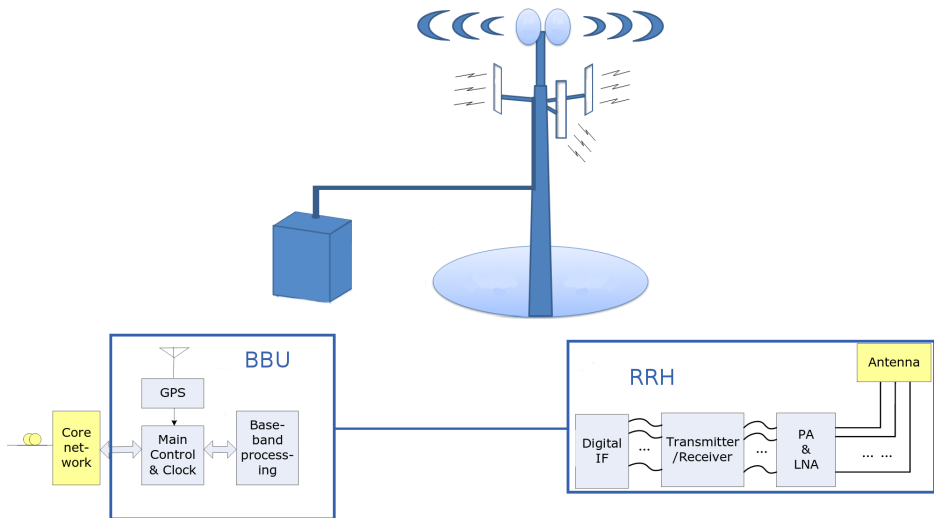
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# Context

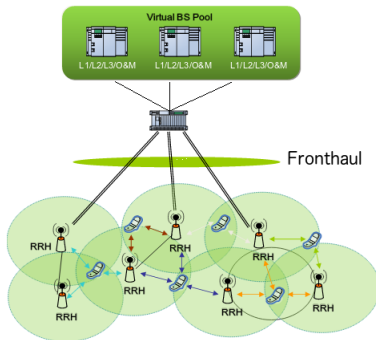


# Use case: Cloud-RAN

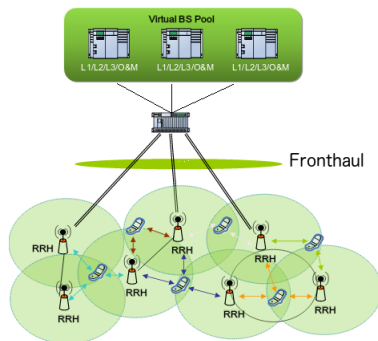


RU=RRH, Distributed/Centralized Unit=BBU

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C-RAN aims to mutualize the computation resources.

Since the processing time is constrained by protocol, the lower the transmission delay, the more important the sharing (ie. the coverage area of a data center).

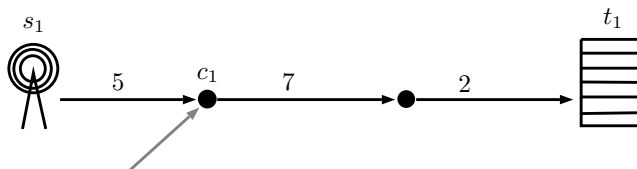
The minimum latency allows to increase the mutualization.

## Specificity of Cloud-RAN:

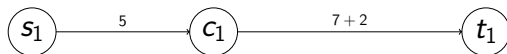
- **Minimize latency**: increase the cover area.
- Periodic traffic

## Current approaches:

- Dedicated network → Too expensive
- Statistical multiplexing (TSN/Qbv) → **bounded latency only**

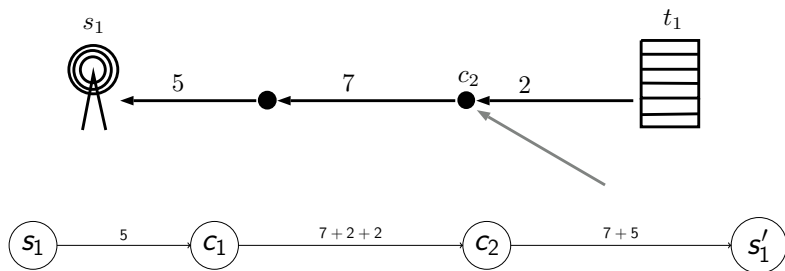


- Network  $\rightarrow$  Weighted DAG
- Physical Delay of a link  $\rightarrow$  Weight of the arc
- Only the contention points are represented in the graph



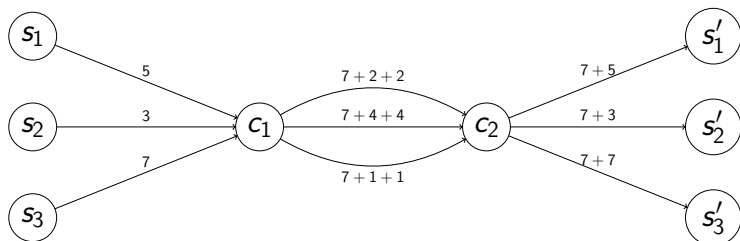
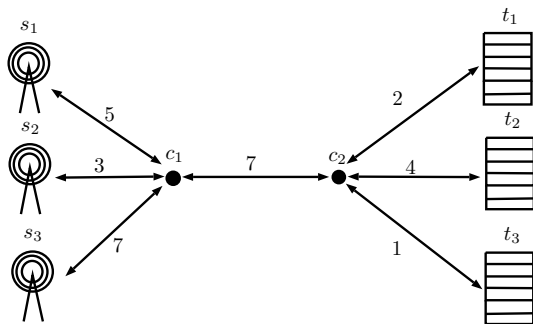
# Model

Both ways: from RRH to BBU (forward) then from BBU to RRH (backward)





# Model



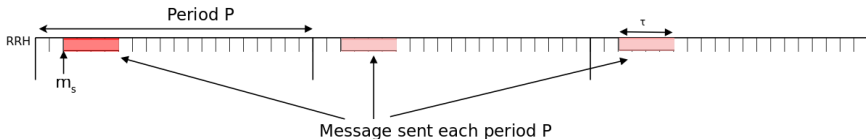
# The communication process

The time is discretized.

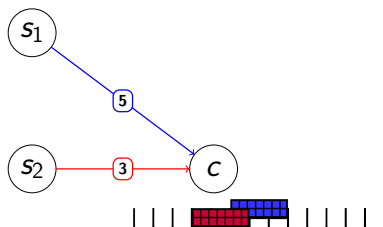
Two fixed parameters determined by the use case.

- The period  $P$
- The size of a message  $\tau$

Every  $P$  units of time, a message of size  $\tau$  is emitted from each RRH.



The process is **periodic** : the message is emitted in each period at the same time, called **offset**.

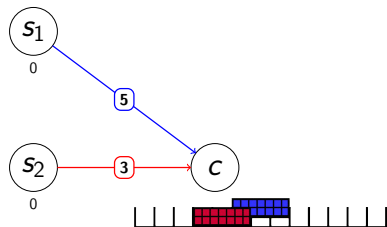


There is a **collision** between two routes when their messages go through the first vertex of a common arc at the same time.

Periodicity must be taken into consideration

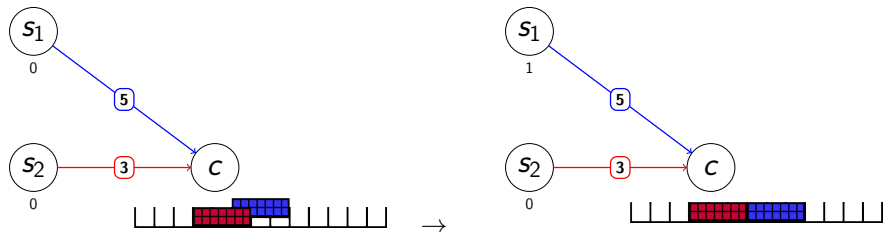
# Assignment

$$P = 13, \tau = 3$$



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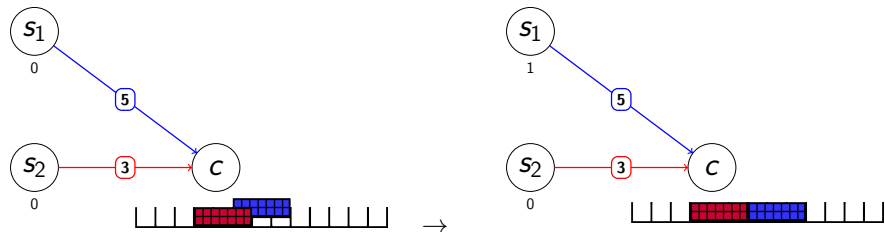
$$P = 13, \tau = 3$$



Choosing the offset such that there are no collisions.

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$$P = 13, \tau = 3$$

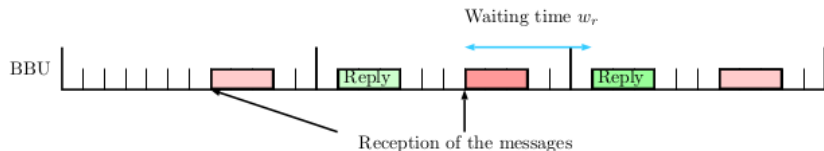


Choosing the offset such that there are no collisions.

An **assignment** is a choice of offsets for each route, without collisions.

# Full process

In each BBU, one can choose the **waiting time** before sending back the answer.



## Problem:

Given a routed network, a period and a message size, find an assignment such that there is no collisions.

Two measures to optimize.

PALL:

- The sources may send their message at different dates in the period.
- Local latency constraint.
- Minimizing the process time on the longest route.
- Use cases: URLLC/Industry 4.0

SPALL:

- The sources send their message at the same date: **Synchronized**.
- Global time constraint.
- Minimize the time between the emission of the first message and the reception of the last message.
- use cases: C-RAN

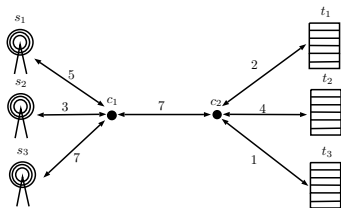
The optimal solutions for PALL and SPALL are not the same.



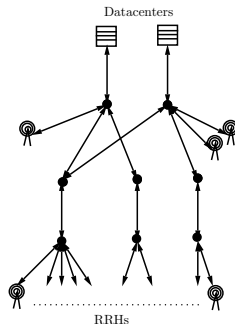
# Different topologies

The **conflict depth** of a route is defined as the number of contention point on the route.

The conflict depth of a routed network is the maximal conflict depth of the routes in the network.



Conflict depth 2.



Conflict depth 3 and more.

## PALL:

- NP-hard on conflict depth  $\geq 3$ :  
reduction from k-coloring problem
- NP-hard on conflict depth 2 if the  
shared arc is not bidirectional.

## SPALL:

- NP-hard on conflict depth  $\geq 3$
- NP-hard on conflict depth 2:  
reduction from two processors  
scheduling problem.

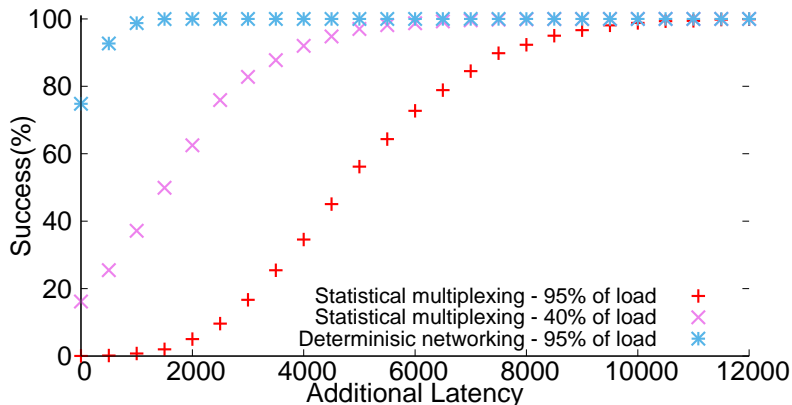
## Conflict depth 2:

- Algorithms with theoretical guarantees for moderate load.
- FPT algorithm based on single processor scheduling. FPT: exponential in  $n$ , the number of routes but linear in  $P$  and  $\tau$

## Conflict depth $\geq 3$ :

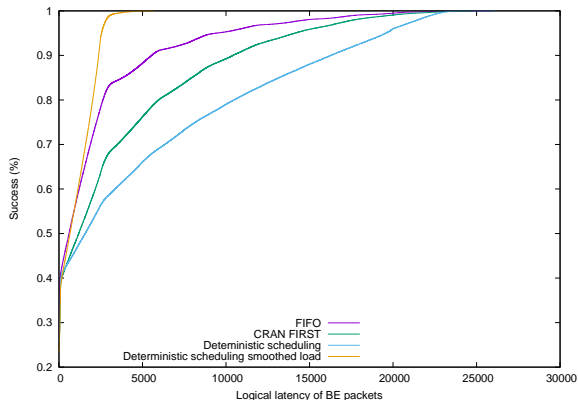
- Local search algorithms (hill climbing, simulated annealing)
- Optimized Branch and bound: computes realistic instances.

# Deterministic vs Statistical multiplexing



Conflict depth 2 - Deterministic = optimal solution  
Period : 20.000 tics

# BE Latency optimization



Conflict depth 2 - Deterministic = optimal solution  
Period : 33.000 tics - CRAN Load : 60% - BE Load  $\simeq$  20%

# Conclusion

- Minimal latency allows higher area coverage: better OPEX
- Deterministic traffic:
  - Zero contention
  - Transparent optical transmission (i.e. without opto-electronic conversion)
  - Energy efficiency
- Better overall traffic on loaded networks

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## Future work

- Performance evaluation for conflict depth  $\geq 3$
- Writing the PhD manuscript

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Thank you for your attention.