Deterministic Scheduling of Periodic Messages for Cloud RAN

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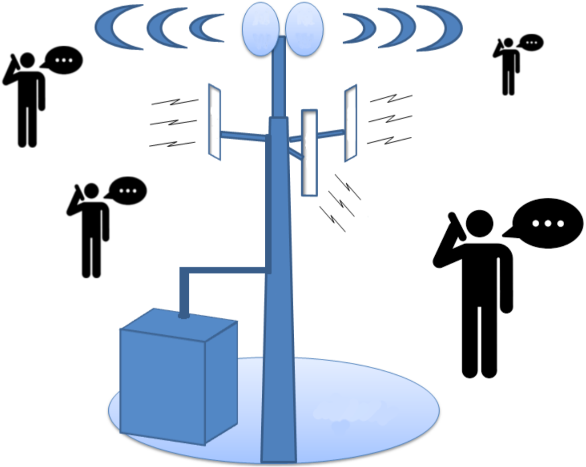
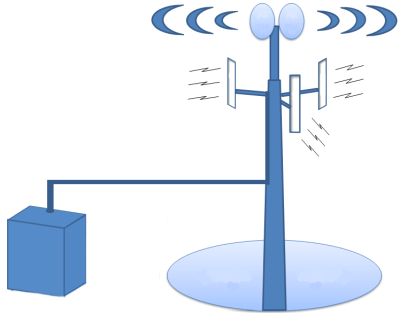
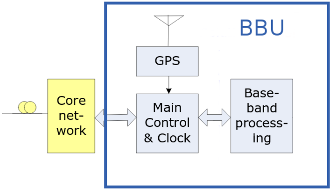
BTS

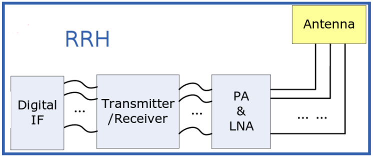
A Base Transceiver Station



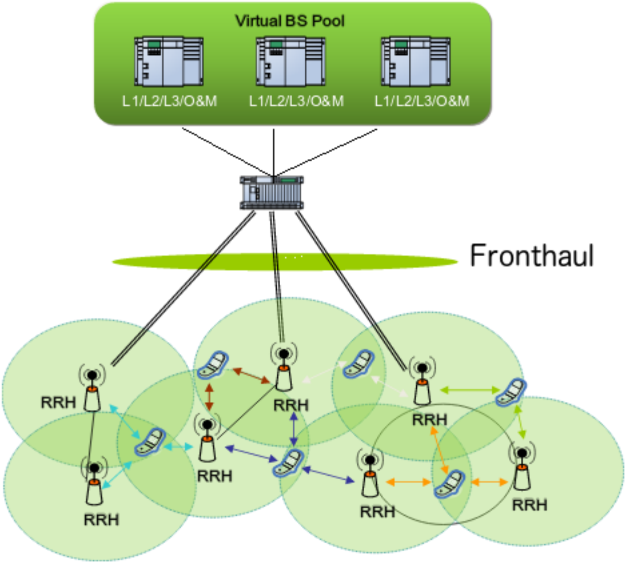
BBU/RRH




BBU
GPS
Core
net-
work
Main
Control
& Clock
Base-
band
process-
ing


Antenna
RRH
Digital
IF
...
Transmitter
/Receiver
...
PA
&
LNA
... ...

Fronthaul



Virtual BS Pool
L1/L2/L3/O&M
L1/L2/L3/O&M
L1/L2/L3/O&M
Fronthaul
RRH
RRH
RRH
RRH
RRH
RRH
RRH

Problematic

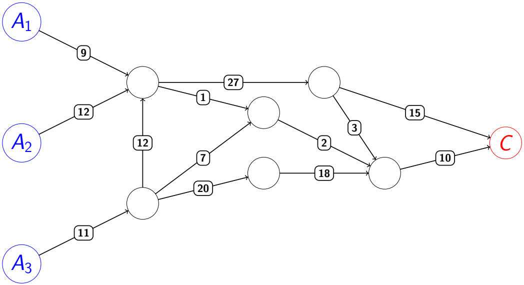
Constraints in Fronthaul network :

- Highly loaded
- Periodic traffic
- Latency must be guaranteed

Current approaches:

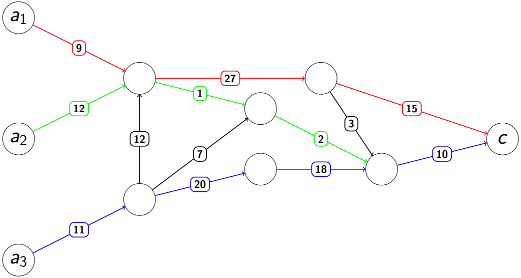
- PtP connections → Too expensive
- Statistical multiplexing → No latency guarantees

Model



- Network : Weighted Directed Graph
- RRH / BBU → set of vertices A (Antennas) and C (Computation)
- Physical Delay of a link → Weight of the arc

Routed Network



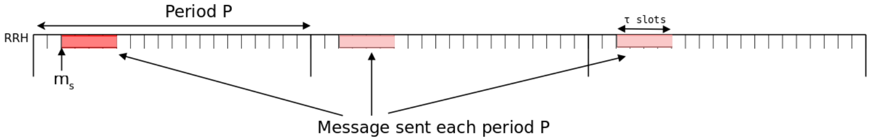
There is a route going from each RRH to the BBU.
A **routed network** : set of routes.

The communication process

Two parameters

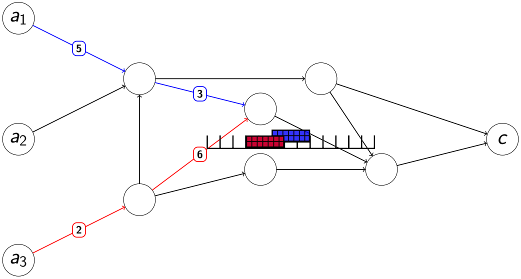
- The period P
- The size of a message τ

The time is discretized and on each route of the network, every P units of time, a message of size τ is emitted.



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

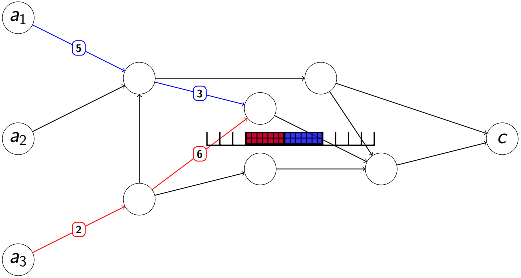
Collisions



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

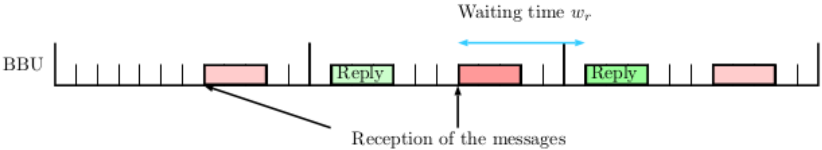


Choosing the offset such that there are no collisions.

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.



The process time of a route is defined by $PT(r) = 2 \times \lambda(r) + w_r$.
$\lambda(r)$ is the length of the route r.

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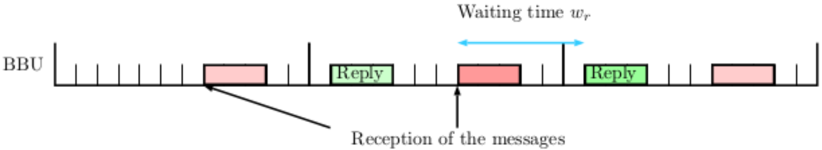

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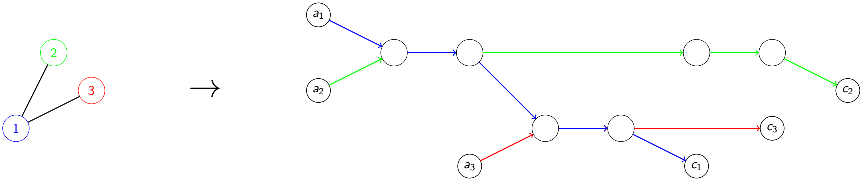
Periodic Assignment for Low Latency (PALL)
Input: A routed network $(G, \mathcal{R})$, the integers P, τ and T_{max}.
Question: does there exist a (P, τ)-periodic assignment of $(G, \mathcal{R})$ such that for all $r \in \mathcal{R}$, $PT(r) \leq T_{max}$?

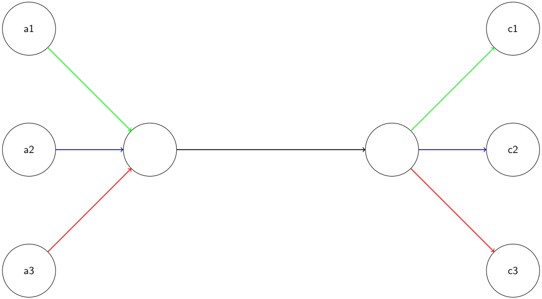
Problem PALL has been shown NP-hard and non-approximable.

NP-Hardness



Reducing an instance of k-coloring into an instance of our problem.

Star network



One link shared by all routes.

No waiting time : solutions

Three proposed solution :

- Send the message from the shortest to the longest route.
  - The size of the period can be determined : $n\tau + 2(\lambda(r_{n-1}) - \lambda(r_0))$
  - Efficient for short routes but clearly bad for long routes.

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  - Bound of the size of the period : $3n\tau$
  - Good complexity : n^2

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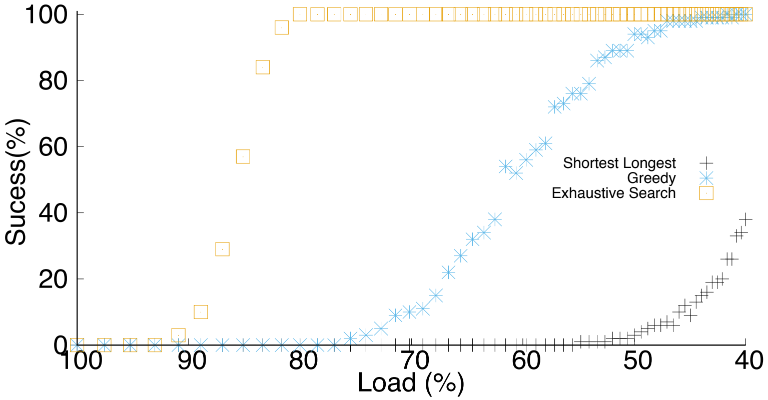
  - Bound of the size of the period : $3n\tau$
  - Good complexity : n^2
- Exhaustive generation
  - Ensures to find a solution if it exists
  - FPT in the number of routes

Results



Not efficient under high loads : need to allow some waiting time.

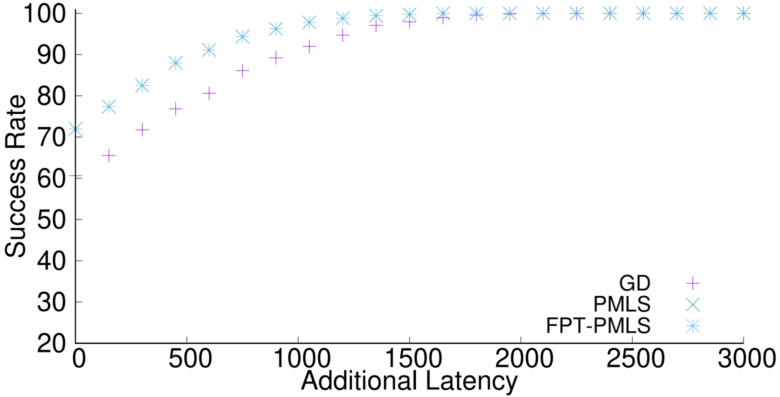
A two stages approach

First step. We fix the offsets of the forward routes according to several heuristics.

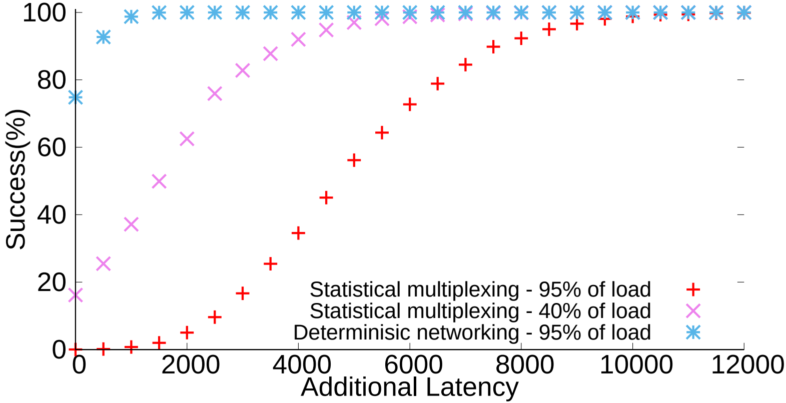
Second step. Algorithms to schedule the backward routes.

- A greedy algorithm (GD)
- Scheduling algorithm adapted for periodicity (PMLS)
- FPT algorithm (FPT-PMLS)

Performances of the algorithms



Deterministic vs Stochastic



Conclusion

- Deterministic scheme outperforms traditional statistical multiplexing for our periodic schemes.

- Next steps : other topologies, fragmented messages, allowing jitter...

Thank you for your attention.