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Performance Evaluation
of Computer Systems and Networks

CRAN 2

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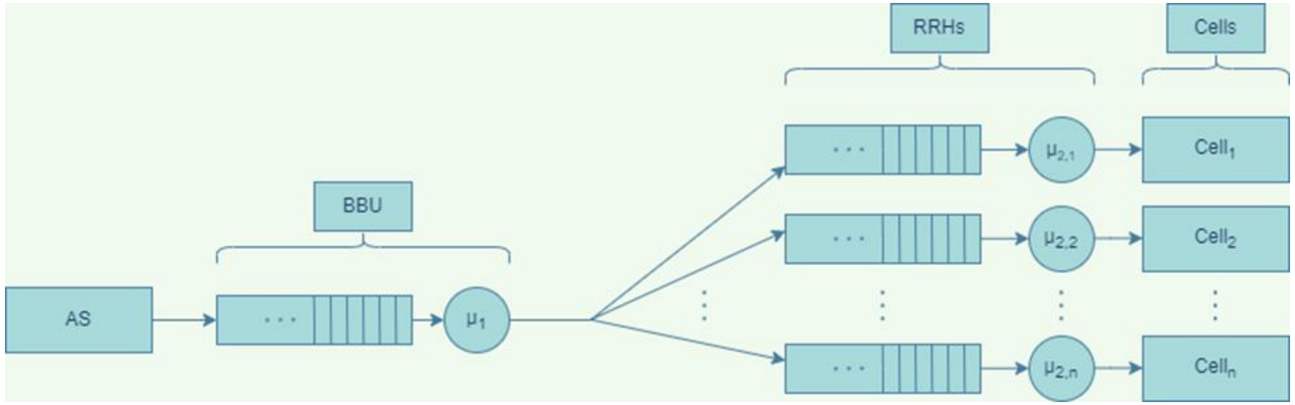
Project Guidelines

- **System description**
  A cellular system is composed of a **BBU** and **N RRH-cell pairs**.
  The packets are sent from the BBU to the RRHs, on a channel with data rate dr, in two ways:
  - ➢ Using **Compression**: the packet is compressed at the BBU and, once at the RRH, is decompressed in S seconds (S = $\alpha * X * 50ms$ where X = compression rate and α is a constant), and then sent to the cell
  - ➢ **Without compression**: once at the RRH the packet is immediately forwarded to the cell



- **Workload**
  - ➢ **Inter-arrival times**, IID RVs with Exponential distribution
  - ➢ **Size of the packets**, IID RVs with Exponential or Lognormal distribution
- **Objectives**
  - ➢ Compare the case with compression with the case without it
  - ➢ Check, in the case with compression, different combination of N, α, X, dr, size mean and size variance (in the case with lognormal distribution)
- **Confidence Interval**
  - ➢ **99% Confidence level** in all experiments

Degeneracy verification

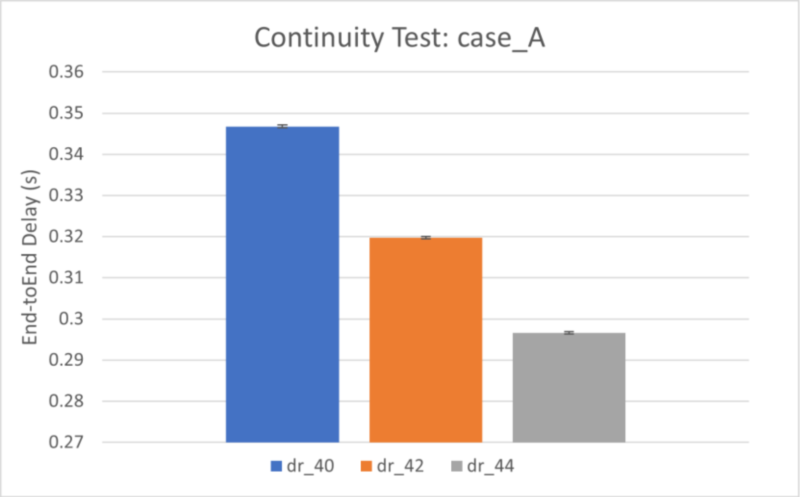
Test performed to analyse the system under extreme conditions, by degenerating some parameters:

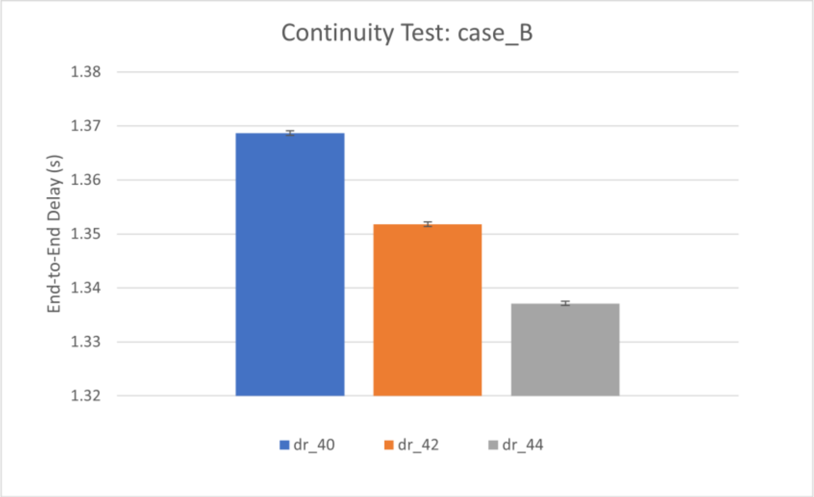
- **E[s] = 0:** mean packet size equal to zero **->** there are no queues nor delays in the system
- **dr = 0:** BBU-RRH link is an ideal channel **->** the average BBU queue is equal to zero
- **dr = 0.1kbps:** very low data rate **->** tendence to infinite queue in the BBU and a very high end-to-end delay

Continuity verification

Check that small changes in the inputs are reflected by small changes in the output.

In our case a change of around 5% in the data rate implies an analogous modification in the End-To-End delay



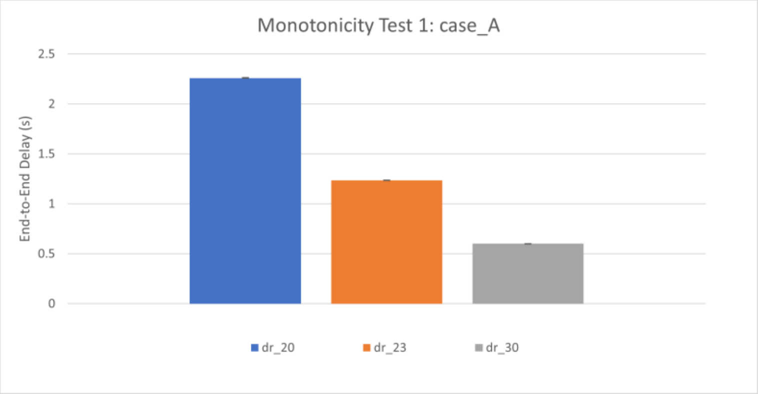


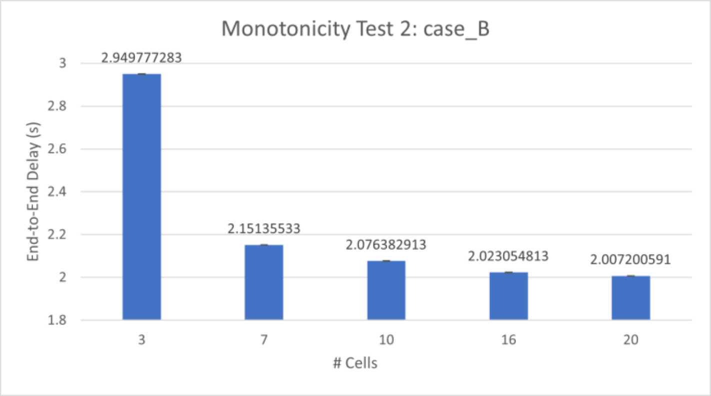
Monotonicity verification

Performed to see if changing some parameters in a specific way will result in a monotonic trend in the end-to-end delay

We checked how End-To-End delay reacts to changes in:

1. Data rate (case_B in the documentation)
2. # of Cells (meaningful only in case_B)



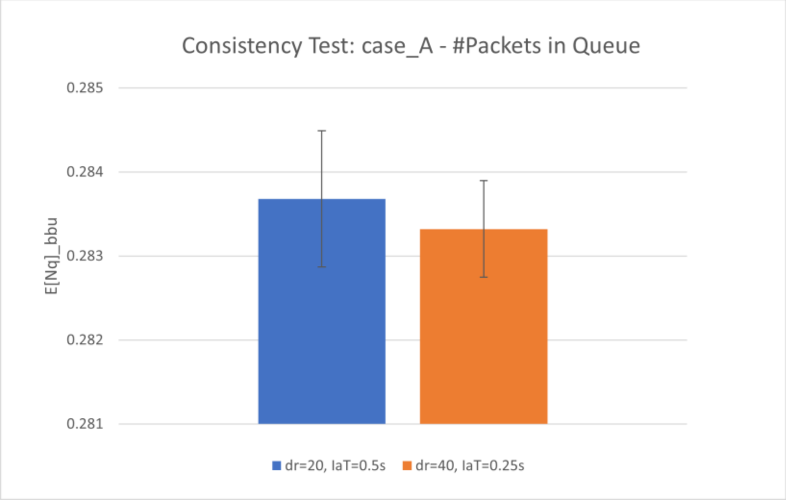


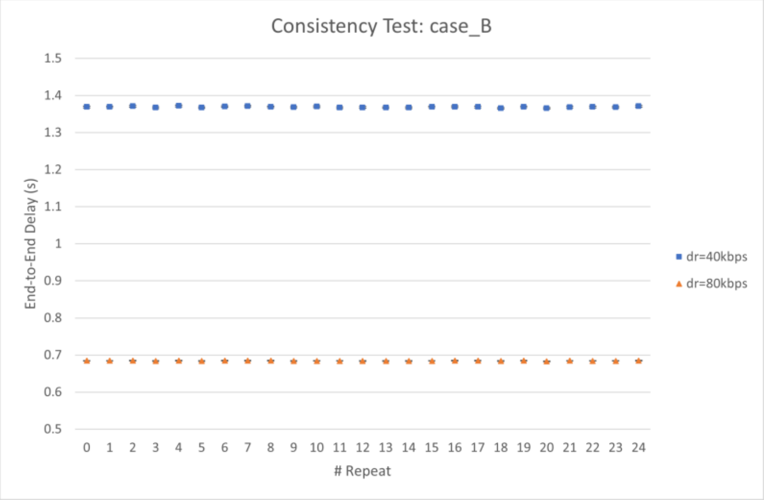
Consistency verification

Carried out observing the mean number of packets in the BBU queue and the end-to-end delay, after halving the mean interarrival time and doubling the channel data rate, keeping the other parameters constant

The results in the figure relative to case_B are explained by the formula:

$$\boldsymbol{E[R]} = \frac{\boldsymbol{E[N]}}{\boldsymbol{\lambda}}$$





Validation against theoretical model

Assumptions:

1. Exponential (Lognormal) packet size distribution
2. Negligible overhead to switch between two packets processing
3. Negligible compression time (into the BBU)
4. No packet-loss or data corruption was considered
5. Sending packets from BBU to RRHs is the service time of the BBU -> negligible transmission time to RRHs
6. Negligible transmission time between RRH-Cell pair
7. RRH-Cell pairs are equal
8. Random packet routing from BBU to RRHs, but with equal probability

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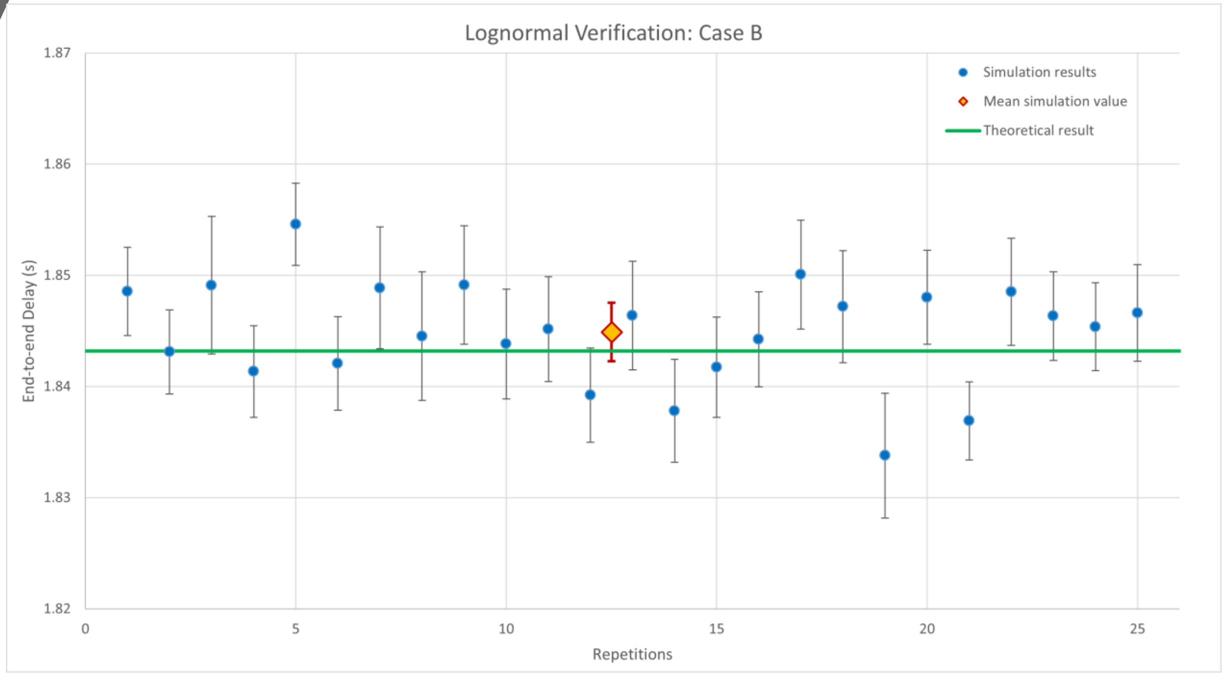
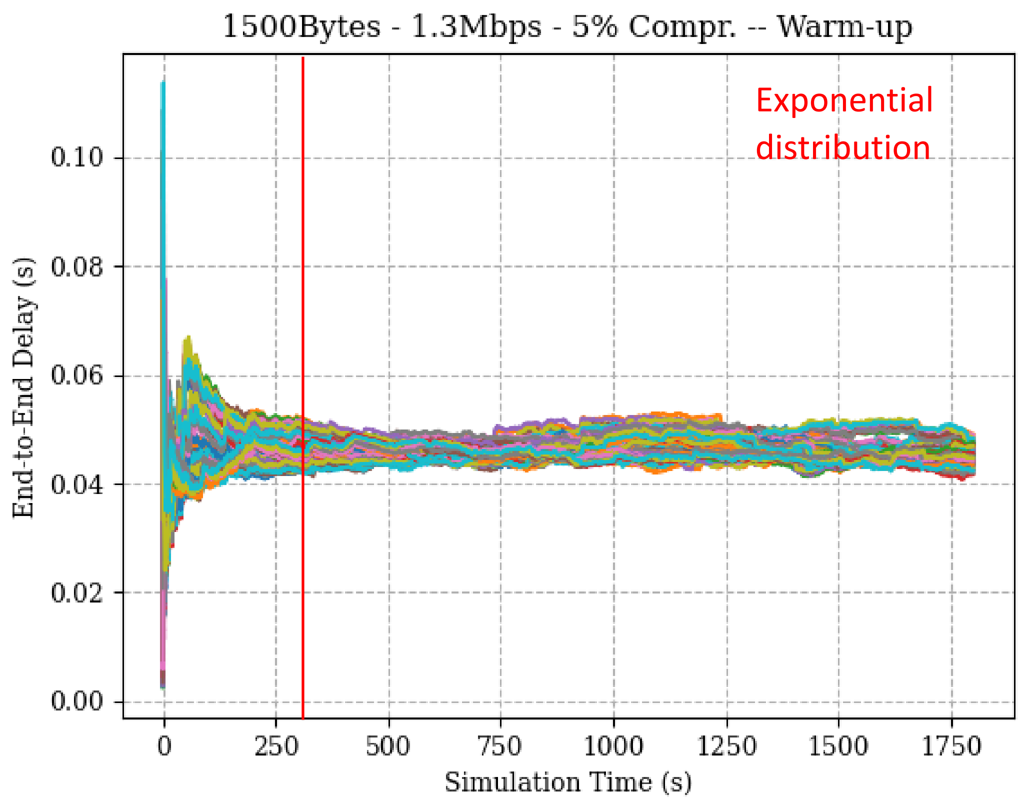
		Packet's size distribution	
		Exponential	Lognormal
Compression	Off	M/M/1	M/G/1
	On	M/M/1 + M/D/N	M/G/1 + M/D/N



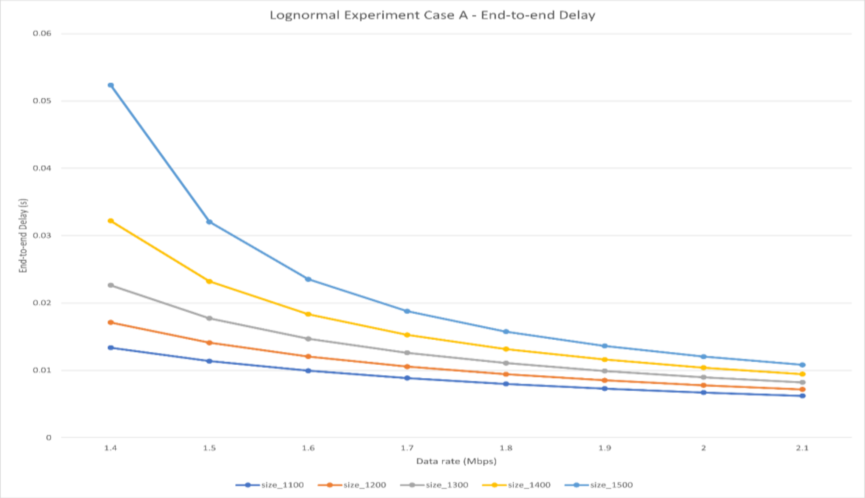
Calibration Phase

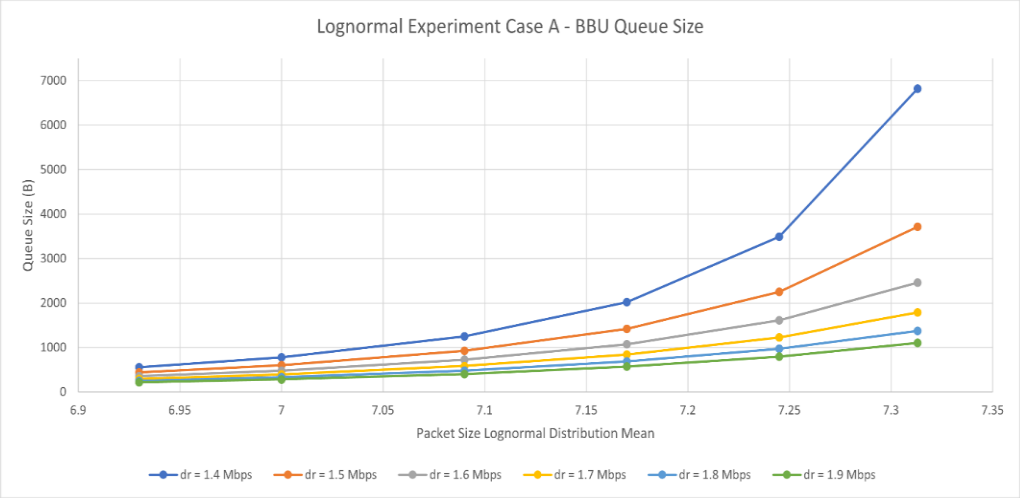
Parameter	Range of Values
Data rate (dr)	[1.3; 2]
Compression (%)	[30; 60]
Std Deviation (σ)	[0.1; 0.5]
Constant alfa (α)	[0.01; 0.015]
Number of cells	[8; 18]
Mean Inter-arrival time	0.01
Mean Packet size	1400 Bytes

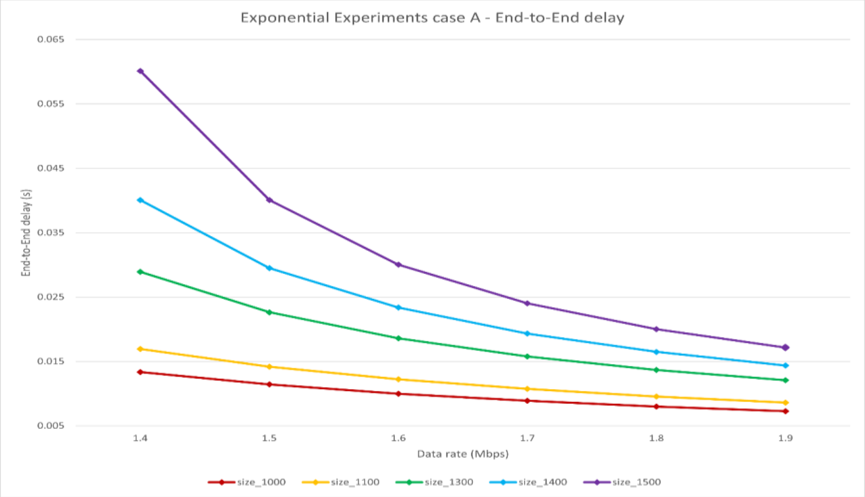
Warm-up period: 350s

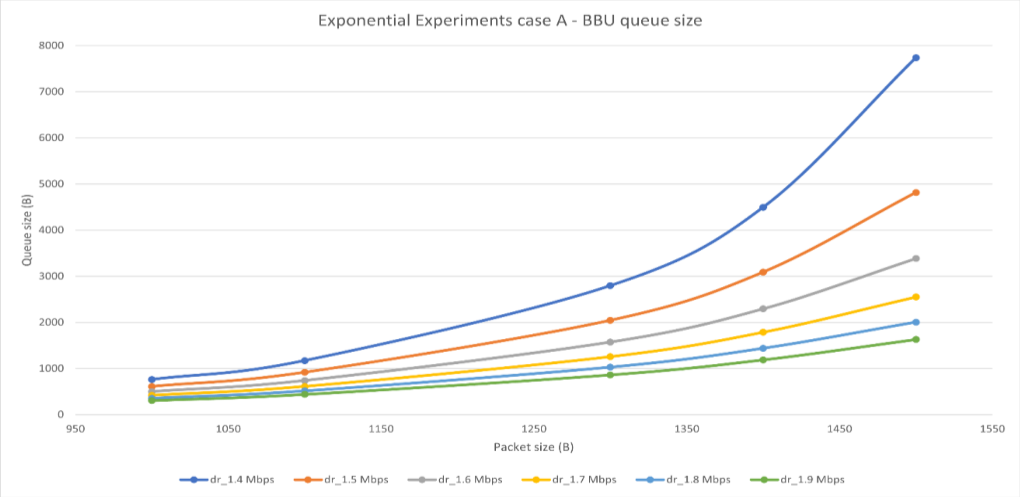


Experiments (Exponential/Lognormal – no Compression)









$2^k r$ Analysis

Performed with parameters set in the calibration phase, ended up with the following main outcomes:

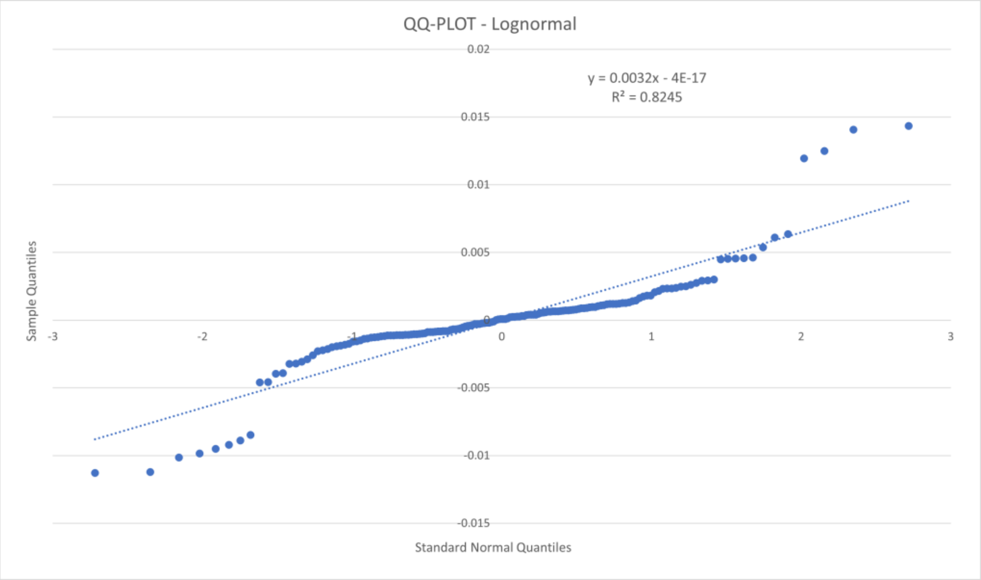
- For the **lognormal distribution**
  - The channel **data rate** affects performance by **14.17%**
  - The **compression** affects performance by **36.46%**
  - The constant **alfa** affects performance by **27.12%**

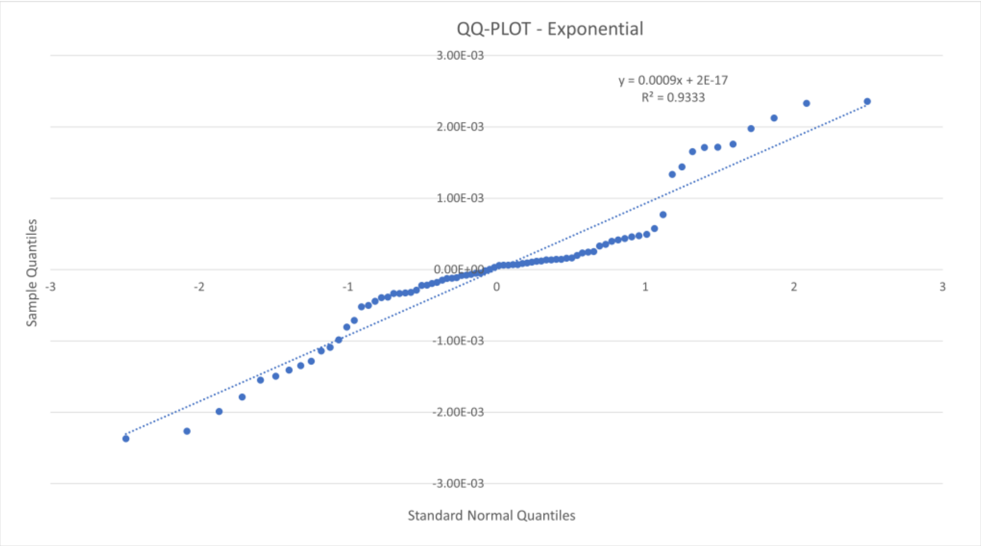
- For the **exponential distribution**
  - The **data rate** affects performance by **23.40%**
  - The **compression** affects performance by **33.43%**
  - The constant **alfa** affects performance by **23.38%**

Negligible errors in both cases.

The result obtained in the lognormal case is **not completely reliable** given that $R^2 \approx 0.82$ even after various transformations.

The **homoskedasticity doesn't show any trend** in both cases.





Experiments
(Exponential – Compression on)

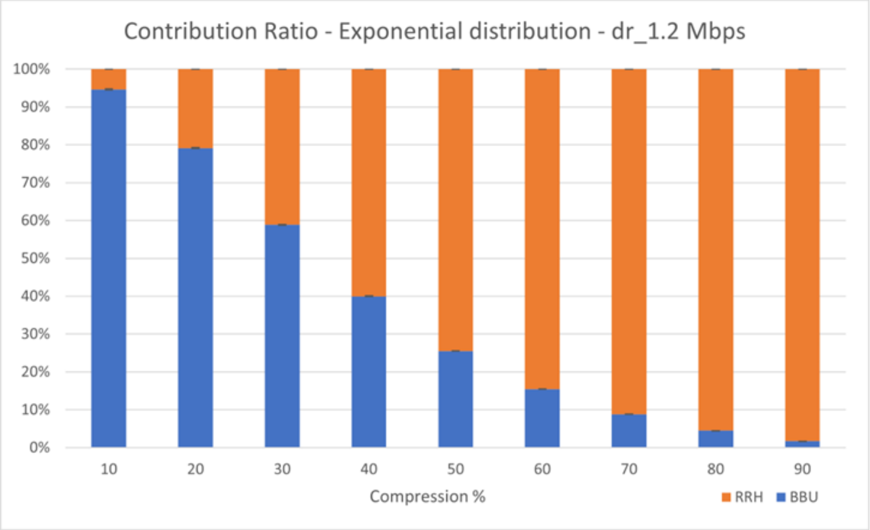
Simulations run with 10 repetitions, obtaining:

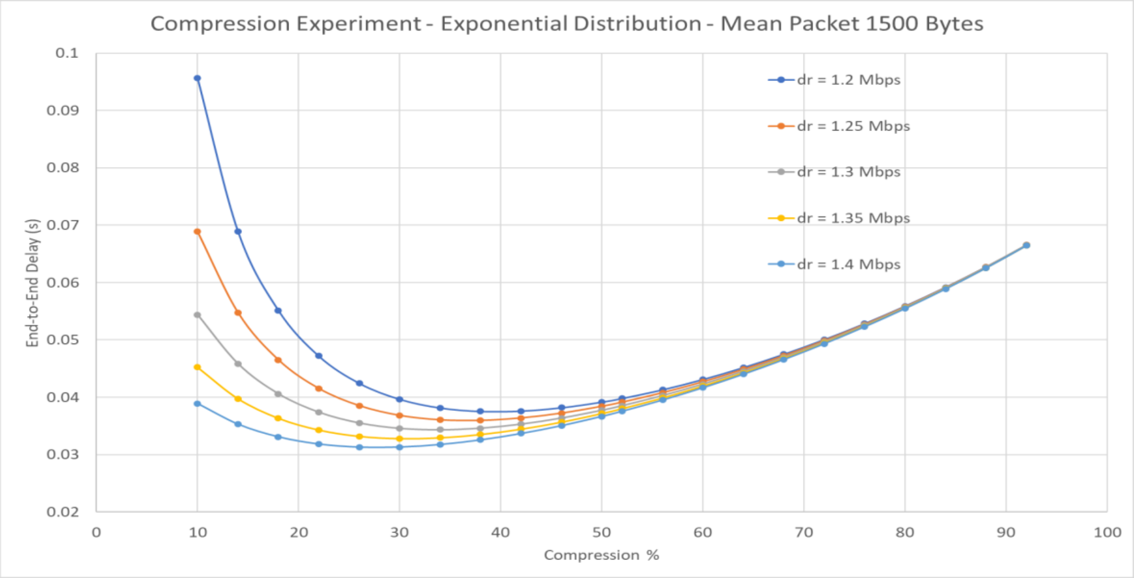
- **Higher compression level:** end-to-end delay most affected by RRH response time
- **Low compression level:** end-to-end delay most affected by BBU response time

This allowed us to find an optimal ratio between the delay generated by the BBU and that by the RRH:

- **BBU is responsible for about 40%** of the overall delay
- **RRH is responsible for about 60%** of the overall delay

Optimal performance reached when the BBU **utilization is in the range [58% ; 64%]**





Experiments
(Lognormal - compression)

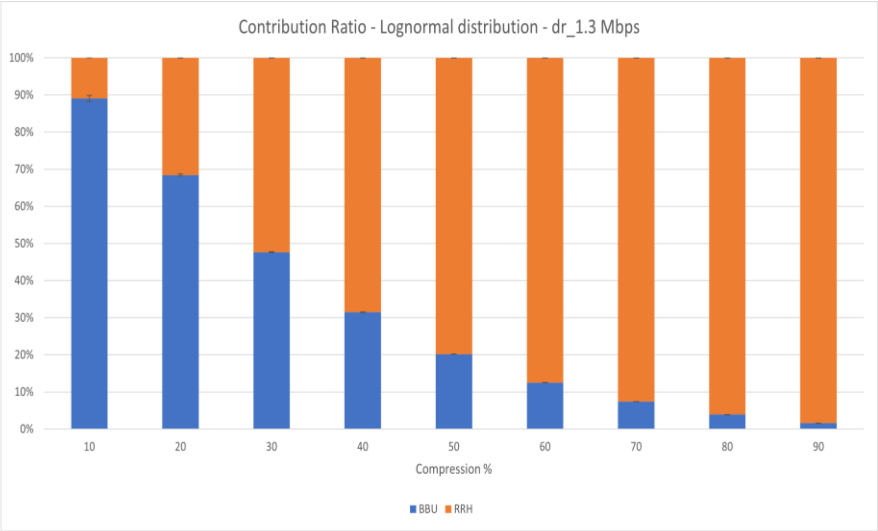
Like previously, simulations run with 10 repetitions, obtaining:

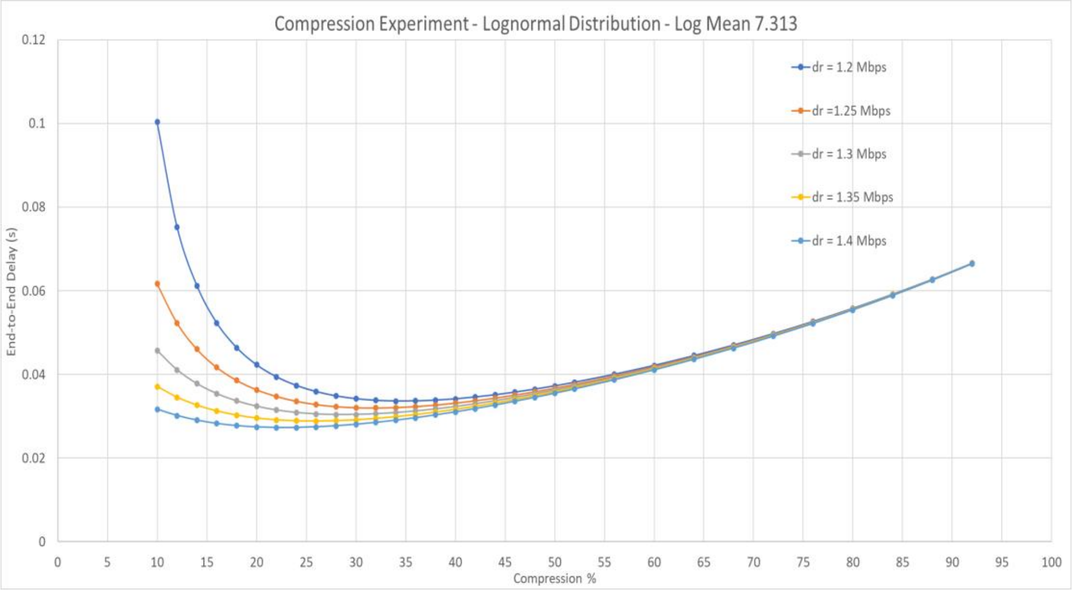
- **High compression level:** end-to-end delay most affected by RRH response time
- **Low compression level:** end-to-end delay most affected by BBU response

This allowed us to find an optimal ratio between the delay generated by the BBU and that by the RRH:

- **BBU is responsible for about 50%** of the overall delay
- **RRH is responsible for about 50%** of the overall delay

Optimal performance reached when the BBU **utilization is in the range [67%; 71%]** .





Experiments (System with different loads)

Fixed the data-rate and testing different mean packet sizes, we found the thresholds for which below the minimum the compression is no longer convenient, and above the maximum it is always convenient, instead, between these it depends

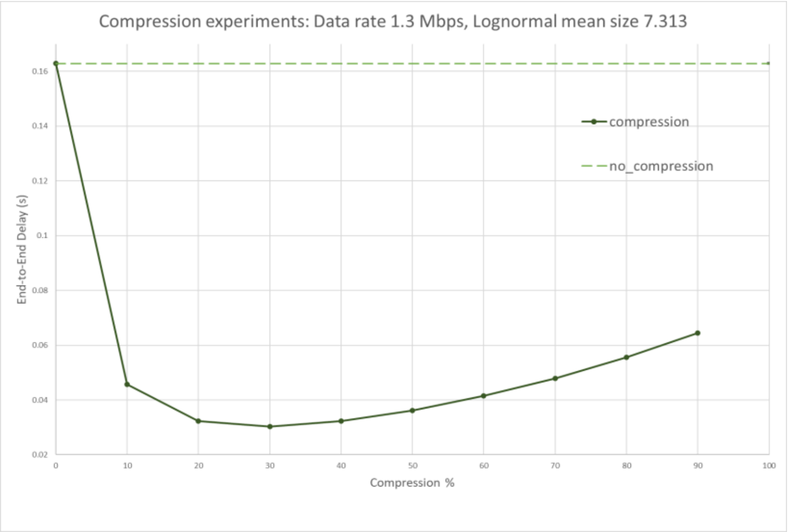
Considering a compression level up to 65% and looking at the BBU utilization, we found that

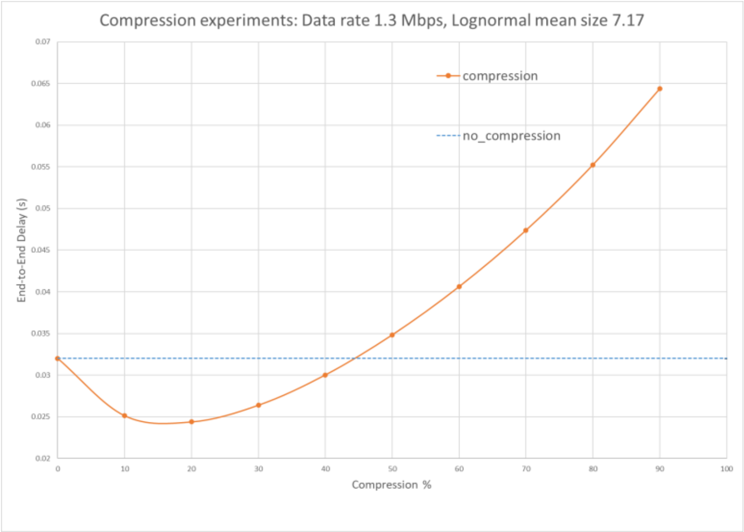
Lognormal case:

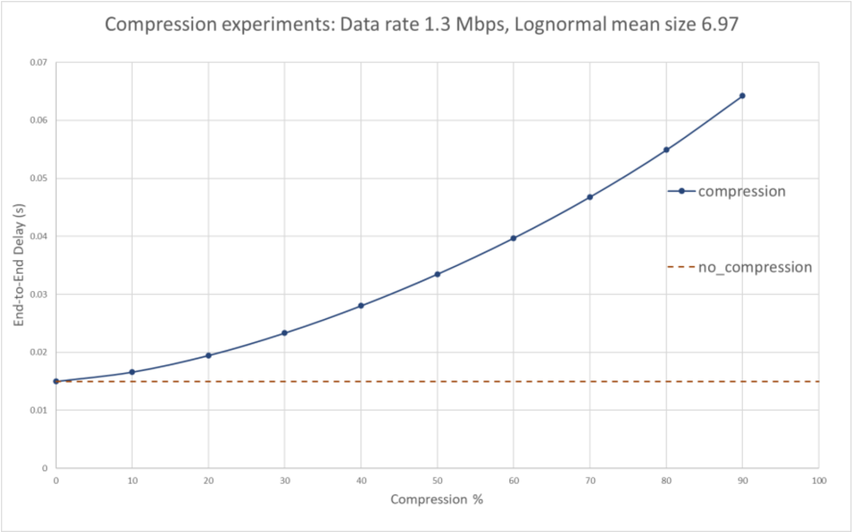
- $\rho_{BBU} < 70\%$ **->** no compression rate convenient
- $70\% < \rho_{BBU} < 87\%$ **->** some compression rates benefit the end-to-end delay and some not
- $\rho_{BBU} > 87\%$ **->** all compression rates improve the performance, w.r.t. without compression

Exponential case:

- $\rho_{BBU} < 65\%$ **->** no compression rate that causes benefit to the system delay
- $65\% < \rho_{BBU} < 81\%$ **->** some compression rates are useful and some not
- $\rho_{BBU} > 81\%$ **->** all compression rates improve the system delay







Conclusion

Compression off -> end-to-end delay influenced by the system load and specially by the data-rate

Compression on -> compression can help to minimize the end-to-end delay and some consideration can be done

Considering a system where the **BBU is the bottleneck**, the compression will help to keep the system in a steady state, reducing the BBU utilization, so in general it can be always convenient, but more precisely:

- With a **low load ->** compression is **no longer convenient** because the delay due to the decompression of the packets in the RRH is greater than the gain of the service time in the BBU
- With **average load ->** there is a **maximum compression threshold** for which compressing packets is better than not doing it
- With **high load ->** compression is **always convenient** because the decompression delay in the RRH is lower than the gain in service time of the BBU

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