Performance and energy efficiency analysis in NGREEN optical network

Youssef AIT EL MAHJOUB

The 12th edition of the Young European Queueing Theorists (YEQT)
Supervisor : Mr. Jean-Michel Fourneau
Co-supervisor : Mrs. Hind Castel-Taleb
Laboratory : DAVID/UVSQ - SAMOVAR/TSP

December 4, 2018
Outline

1. Introduction
2. Model for optical container filling
3. Modeling the container insertion on the optical ring
4. Energy efficiency and latency analysis
5. Concluding remarks
Introduction

Model for optical container filling

Modeling the container insertion on the optical ring

Energy efficiency and latency analysis

Concluding remarks
Ngreen

- The NGREEN project [1, 2] is partially funded by the ANR, coordinated by NOKIA / Alcatel-Lucent Bell Labs France which collaborate with DAVID laboratory (as well as other laboratories).

- This project aims to design and validate a low-cost and low-power network architecture.

- Ring topology with Broadcast and Select mode.

- Radio transportation in the optical container ⇒ low latency required.

- From a performance point of view, we try to minimize latency and maximize the network utilization.
**Second step**: Insertion in the ring

**First step**: Container filling

**Figure 1** – Architecture of NGREEN network [1, 2]
Goals of the study

- Developing mathematical models in order to analyze aggregation efficiency and end to end delays.

\[ T_{\text{Inter-PDU}} = T_{\text{EmptyBatch}} + T_{\text{Fillling}} \]  
\[ T_{\text{End-to-End}} = T_{\text{Inter-PDU}} + T_{\text{Insertion}} + T_{\text{transport}} \]

- Comparing the insertion time in opportunistic and slot reservation mode.

- Studying the trade-off between energy efficiency and delays.
Introduction

Model for optical container filling

Modeling the container insertion on the optical ring

Energy efficiency and latency analysis

Concluding remarks
• Let $X_n$ be the number of SDUs (Service Data Units) in the buffer at time $n$ and $H_n$ be the value of the timer.

• $(X_n, H_n)$ is a finite Discrete Time Markov Chain.

• Filling constraint: A **Deadline** for the timer or a **Threshold** for the PDU’s (Protocol Data Unit) size.

• The system evolution equations:

  \[
  X_{n+1} = \min(X_n + A_n, BufferSize) \tag{3}
  \]

  \[
  \text{If } (X_{n+1} > 0) \Rightarrow H_{n+1} = \min(H_n + 1, \text{Deadline}) \tag{4}
  \]

  \[
  \text{If } (H_{n+1} = \text{Deadline}) \Rightarrow \text{Container ready} \tag{5}
  \]

  \[
  \text{If } (X_{n+1} \geq \text{Threshold}) \Rightarrow \text{Container ready} \tag{6}
  \]
Introduction
Model for optical container filling
Modeling the container insertion on the optical ring
Energy efficiency and latency analysis
Concluding remarks

Numerical Analysis:

- Steady state distribution: new numerical algorithm that we propose and prove. The complexity is \( O(m) \).
- 0.01s instead of 595s (GTH), for a 5200 states Markov chain.
- Property of the chain [3]: the only existing cycles go through the same state (the root state (0,0)).
- Calculation of the filling time distribution.
- Calculation of the containers size distribution.

**Figure 2 – Filling process Markov chain**
Figure 3 – (a) Distribution of the arrival time between two PDUs. (b) Mean filling time versus deadline, for different threshold ratios.
Outline

1. Introduction
2. Model for optical container filling
3. Modeling the container insertion on the optical ring
4. Energy efficiency and latency analysis
5. Concluding remarks
Opportunistic insertion mode:

- We build a discrete time simulator where time unit is the « time slot ».
- Parameters: A ring of 150 slots, global time is considered, stations can send/receive containers following the Broadcast and Select mode.
- The distribution of inter-arrivals containers correspond to the distribution of the time to fill a container (which we get from the last section).
Slot reservation insertion mode:

- A station can only use the slots that are periodically reserved for it.
- We consider a discrete time model based on two clocks: $H_1$ (bounded by a period $D$) to model the arrival of a reserved slot on the ring and $H_2$ (bounded by the Max-Arrivals) to model the inter-arrival of an optical container.
- Let $X$ be the population of containers. Clearly $(H_1, H_2, X)_n$ is a finite Discrete Time Markov Chain.
Opportunistic insertion VS Slot reservation mode

Figure 4 – Case of 22 stations which gives a ring occupancy of 70%

Opportunistic mode, mean = 3.43

Slot Reservation mode, mean 10.91
Opportunistic insertion VS Slot reservation mode

Figure 5 – Insertion delay in both modes
Outline

1. Introduction
2. Model for optical container filling
3. Modeling the container insertion on the optical ring
4. Energy efficiency and latency analysis
5. Concluding remarks
We consider a scenario with 10 stations.

Whether a container is empty or full, it consumes the same energy.

Energy efficiency:

\[
\frac{0.8 \times 10^{-9} \times \text{ContainerCapacity} \times 8}{\text{The Payload}} = \frac{80 \ \mu \text{Joules}}{\text{The Payload}} \tag{7}
\]

We study the trade-off between energy efficiency and latency (end-to-end delay).
Energy efficiency versus deadline.

End to end delays versus deadline.

**Figure 6** – Energy efficiency VS Latency
Outline

1. Introduction
2. Model for optical container filling
3. Modeling the container insertion on the optical ring
4. Energy efficiency and latency analysis
5. Concluding remarks
Conclusion

- NGREEN ⇒ Ring topology, new optical technologies (OSS - Optical Slot Switching, WDM - Wavelength Division Multiplexing).
- No routing problems ⇒ dealing with delays to access the ring (filling time + insertion time + transport time).
- Developing mathematical models in order to analyze aggregation efficiency, proposing a new algorithm with a linear complexity.
- Trade-off between energy efficiency and Latency.
- Generalization to non stationnary SDUs arrivals?
  ⇒ Huge matrix size, block structured Markov chain ... see paper [2] for more details.
Bibliography

Youssef Ait el mahjoub, Jean-Michel Fourneau, Hind Castel-Taleb. Performance and energy efficiency analysis in NGREEN optical network. WIMOB (2018).

