Performance and energy efficiency analysis in NGREEN optical network

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Outline

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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.

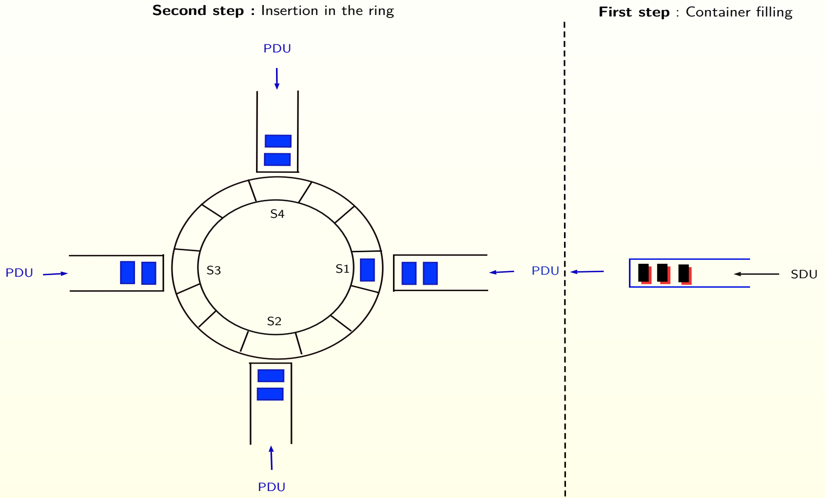


FIGURE 1 – Architecture of NGREEN network [1, 2]

Goals of the study

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

$$T_{Inter-PDU} = T_{EmptyBatch} + T_{Fillling} \quad (1)$$

$$T_{End-to-End} = T_{Inter-PDU} + T_{Insertion} + T_{transport} \quad (2)$$

- Comparing the insertion time in opportunistic and slot reservation mode.
- Studying the trade-off between energy efficiency and delays.

Outline

- 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 :

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

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

$$If(H_{n+1} = Deadline) \;\Rightarrow\; Container\;\; ready \tag{5}$$

$$If(X_{n+1} \geq Threshold) \;\Rightarrow\; Container\;\; ready \tag{6}$$

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.

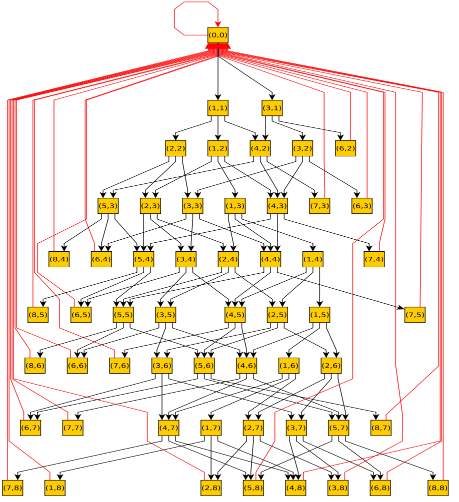
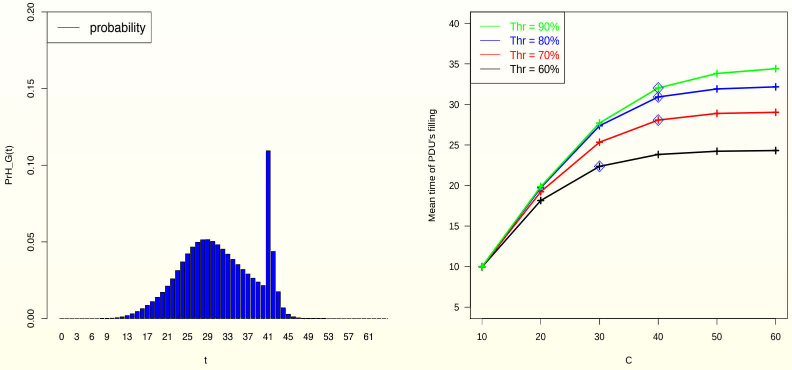


FIGURE 2 – Filling process Markov chain



(a) (b)

FIGURE 3 – (a) Distribution of the arrival time between two PDUs. (b) Mean filling time versus deadline, for different threshold ratios

Outline

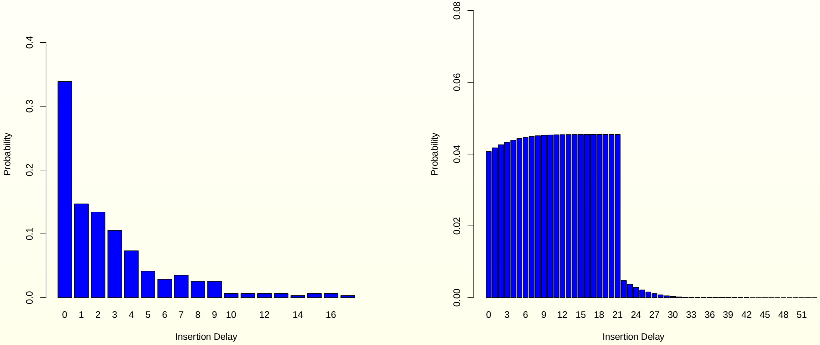
Opportunistic insertion mode :

- 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 : **H1** (bounded by a period **D**) to model the arrival of a reserved slot on the ring and **H2** (bounded by the Max-Arrivals) to model the inter-arrival of an optical container.
- Let **X** be the population of containers. Clearly $(\mathbf{H1}, \mathbf{H2}, \mathbf{X})_n$ is a finite Discrete Time Markov Chain.

Opportunistic insertion VS Slot reservation mode



Opportunistic mode, mean = 3.43 Slot Reservation mode, mean 10.91

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

Opportunistic insertion VS Slot reservation mode

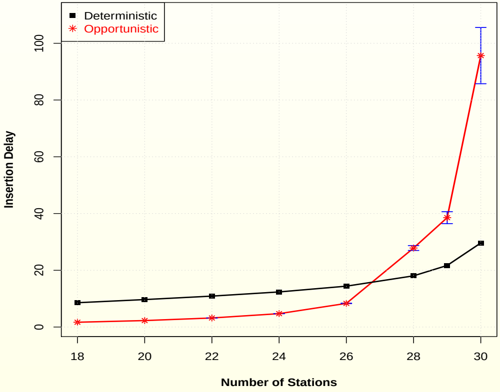


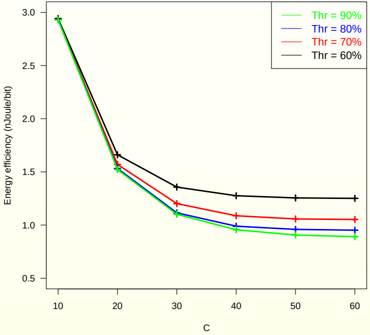
FIGURE 5 – Insertion delay in both modes

Outline

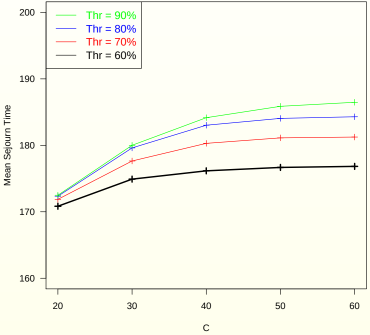
- We consider a scenario with 10 stations.
- Whether a container is empty or full, it consumes the same energy.
- Energy efficiency :

$$\frac{0.8x10^{-9}xContainerCapacityx8}{The\ Payload} = \frac{80\ \mu Joules}{The\ Payload} \tag{7}$$

- 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

Conclusion

- NGREEN $\Rightarrow$ Ring topology, new optical technologies (OSS - Optical Slot Switching, WDM - Wavelength Division Multiplexing).
- No routing problems $\Rightarrow$ 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 ?
  $\Rightarrow$ Huge matrix size, block structured Markov chain ... see paper [2] for more details.

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