A Model for Estimating IoT Gateway Media Access Control Virtualisation Delays

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1. Abstract/Summary

Virtualisation is one of the most effective ways of providing scalability of network functions like the Media Access Control (MAC) scheduling function for Internet of Things (IoT) Gateways.

The virtualisation process introduces additional delays which can counter the aim of scaling of the MAC functions. Therefore a model that can estimate such delays is imperative. However, this is a key challenge due to the complexity of the MAC virtualisation process.

In this study, a virtualisation framework is proposed, and a suitable analytical model is developed to estimate the virtualisation delays imposed by key components of the virtualisation process.

The model is verified by analysing the results based on a test case scenario. The results obtained indicate that, higher delays occur with increasing number of virtual MAC (vMAC) instances which in turn depend on the type of vMAC and the optical link used for transmission.

2. Introduction

Virtualisation of the MAC scheduling functions means that, the MAC functions are separated from the gateway (GW) device and deployed onto a remote data centre.

This requires additional network components that can lead to increased latency in the transmission of vMAC scheduling frames.

Existing models like in [1], omit the MAC scheduling related functions like acknowledgement (ACK) and synchronisation (SYC) transmissions due to strict timing deadlines. Also, some virtualisation components such as encapsulation, switching and line transmissions are omitted in order to simplify the models.

These omissions do simplify the models but do not provide a true representation of the MAC function virtualisation .

Therefore, the approach proposed in this study takes into account the ACK, SYC and Payload (PLD) frames which are essential for the MAC scheduling of devices of IoT GWs.

The approach also incorporates a Common Public Radio Interface (CPRI) protocol encapsulation, priority-based virtual frame switching and Optical fibre transmission. The edge data centre aspect is not considered in this study.

The rest of the poster highlights the aim and objectives of the study, the methodology employed, the results obtained and the conclusions drawn from this study.

3. Research Aims and Objectives

Research Aim

- To develop a model for estimating delays imposed by a MAC virtualisation process.

Research Objectives

- To develop a virtualisation framework for the virtualisation process.
- To model the delay of each virtualisation process.
- To model the vMAC traffic arrival rate parameters
- To model the queuing delay through synthesis of the arrival rate parameters and processes.
- To analyse the impact of the virtualisation components on the latency of vMAC traffic.

4. Methodology

Virtualisation framework design

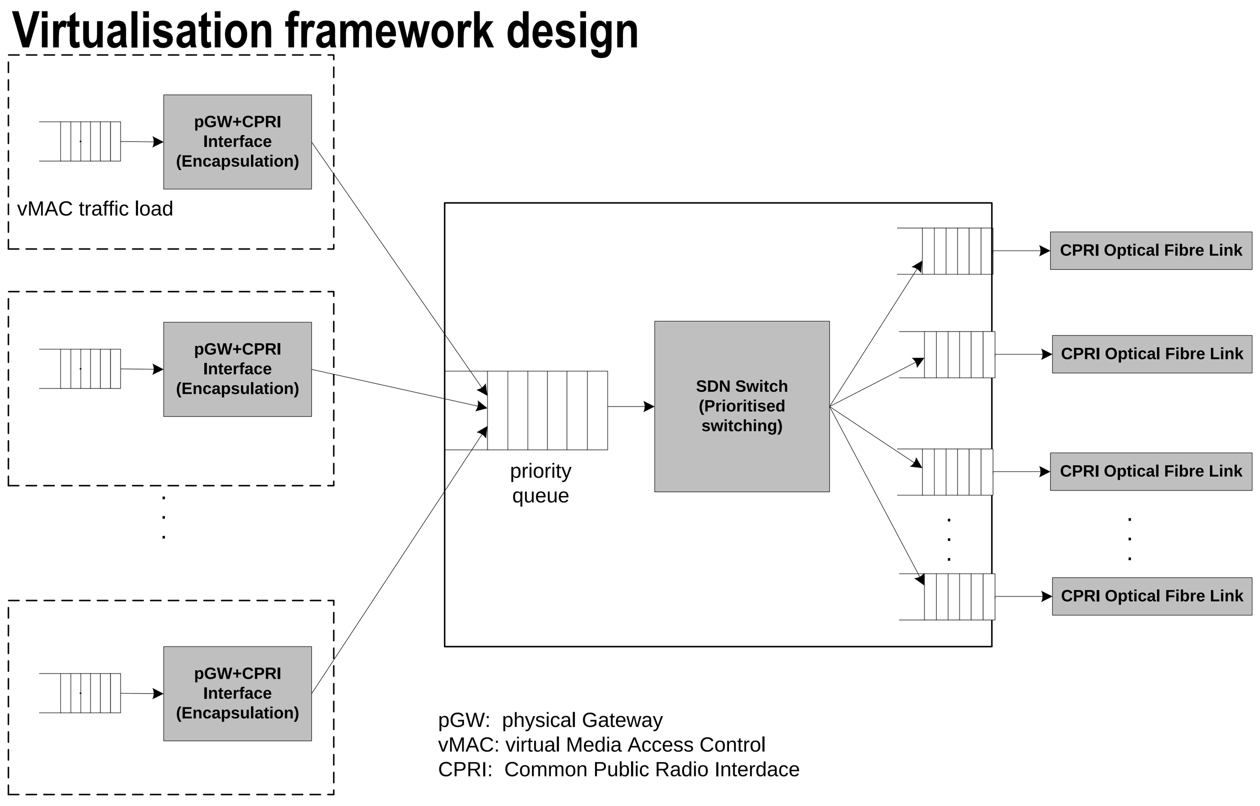

Fig. 1: Framework with the different processes and components

CPRI Encapsulation process:

The CPRI encapsulation time (T_{CF}) is modelled based on the CPRI standardisation document [2].

$$T_{CF} = \frac{L_{CF}}{R_{CPRI}} = n_{BF} \times 260.416\, ns \qquad (1)$$

CPRI Optical link transmission process:

The Optical fibre transmission time (T_{opt}) is modelled using Shannon's capacity theorem including cross talk noise.

$$T_{opt}\left(D_{opt}^{\ell ij}, n_c\right) = \frac{D_{opt}^{\ell ij}}{n_c B_D \log_2\left(1+\frac{P_e}{N_{XT}}\right)\times 10^6} \qquad (2)$$

Traffic Arrival rate parameters:

The total traffic load at the pGW (λ_{0p}) is modelled using the principle of superposition of traffic arrivals for SYN, ACK and PLD, the number of devices and number of vMAC instances.

$$\lambda_{0p} = \sum_{V_e} \sum_{M} \frac{\lambda_M}{L_M} N_D(v_k') \qquad (3)$$

The QNA model [3] is used to obtain the traffic arrival rate λ_j, and the variability of arrivals c_{aj}^2, at each component.

$$\lambda_j = \lambda_{0j} + \sum_{i=1}^{n} \lambda_i \gamma_i p_{ij} \qquad (4)$$

$$c_{aj}^2 = a_j + \sum_{i=1}^{n} c_{ai}^2 b_{ij}, \quad 1 \le j \le n \qquad (5)$$

Queuing delay:

Using the parameters obtained in (1), (2), (3), (4) and (5), together with the utilisation ρ_j at each component, the average queuing delay of vMAC frames at each node is modelled using the Langenbach-Belz approximation [3].

$$W_j = \frac{\tau_j \rho_j \left(c_{aj}^2 + c_{sj}^2\right) g_i}{2(1-\rho_j)} \qquad (6)$$

Equation (6) is slightly modified to give (7), to cater for the priority-based scheduling of vMAC frames.

$$W_{jq} = \begin{cases} W_{jq}, & q = 1 \\ W_{jq} + \sum_{\bar{q}=1}^{q-1} W_{j\bar{q}}, & 2 \le q \le n_q \end{cases} \qquad (7)$$

Virtualisation delay in this work is considered as the average queuing time or delay before a service at each component.

5. Results

Test Scenario

- 4 vMAC types,q1(highest priority), q2, q3 ,q4(lowest priority).
- q1 carries the most MAC traffic followed by q2, q3 and q4.
- 4 pGW devices with only one (pGW 1) having 8 vMACs (2 vMACs for each type) to be deployed.
- All q4 vMACs are deployed first, followed by q3, q2, and q1.
- q1 vMACs are routed to link 1, q2 to link 2, q3 to link 3 and q4 to link 4.
- All the CPRI optical links have the same distance (20 Km).

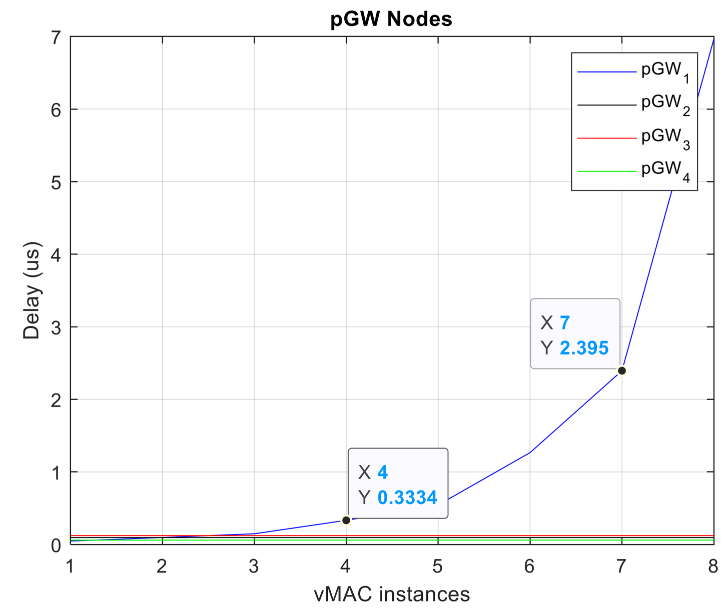

Fig. 2: Delay at the pGW. Delay increases with increasing vMAC instances for pGW 1. This is expected because all 8 vMAC instances are for pGW 1 hence pGW 1 has more traffic load. High loads causes high delays.

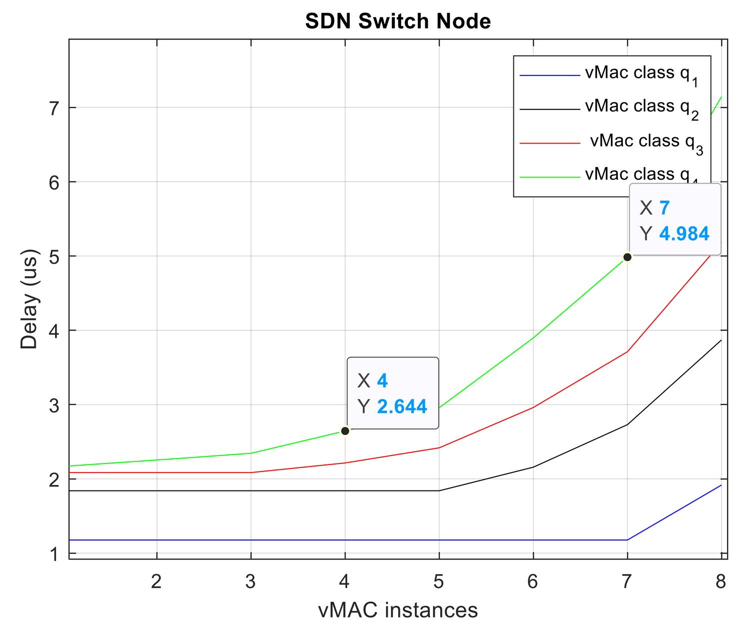

Fig. 3: Delay at the SDN. Delay increases with increasing vMAC instances. vMAC type q1 has the least delay and q4 has the highest delay. This is expected because q1 is given the highest transmit priority and q4 is given the least.

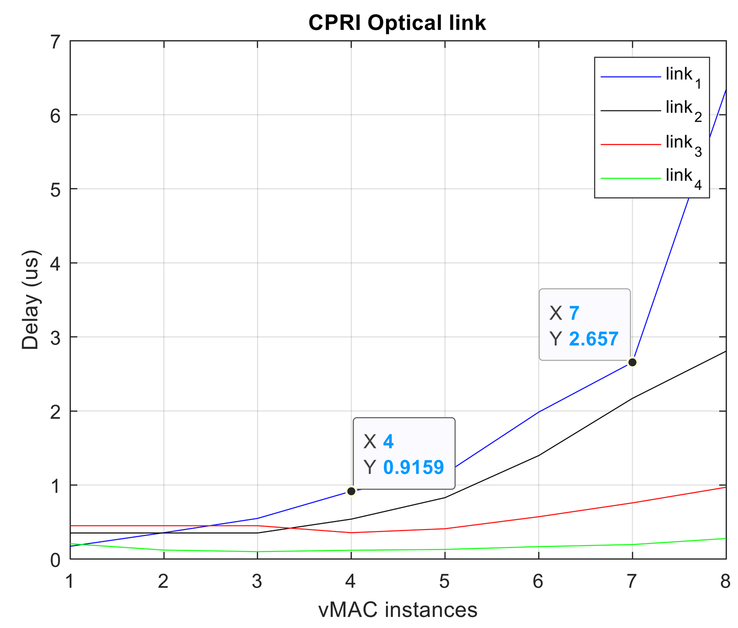

Fig. 4: Delay at the CPRI Optical links. Delay increases with increasing vMAC instances. Link 1 has the most delay and link 4 has the least delay. This is expected because, the high priority vMAC which has the most traffic, is routed on link 1 where as q4 carrying the least traffic is routed on link 4.

Conclusion

- The framework developed encompasses the relevant components and processes for virtualising the MAC scheduling function. (Encapsulation, Switching and Optical link, ACK, SYC and PLD transmissions).
- The model approximates the latency of each virtualisation component, the arrival rate parameters and queueing delay.
- The Results presented indicate that the virtualisation delay generally increases with increasing vMAC instances which also depends on the type of vMAC (traffic rate) and the link selected for transmission.
- Future work may add the edge data centre processing component.

References

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