Estimating the end-to-end energy consumption of IoT devices along with their impact on Cloud and telecommunication infrastructures

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***Abstract*—Information and Communication Technology takes a growing part in the worldwide energy consumption. One of the root causes of this increase lies in the multiplication of connected devices. Each object of the Internet-of-Things often does not consume much energy by itself. Yet, their number and the infrastructures they require to properly work have leverage. In this paper, we combine simulations and real measurements to study the energy impact of IoT devices. In particular, we analyze the energy consumption of Cloud and telecommunication infrastructures induced by the utilization of connected devices, and we propose an end-to-end energy consumption model for these devices.**

***Index Terms*—component, formatting, style, styling, insert**

I. Introduction [2 col]

II. Related Work [1 col]

III. Use-Case [1 col]

A. Application Characteristic

B. Cloud Infrastructure

IV. System Model [2 col]

The system model is divided in two parts. First, the IoT and the Network part are models through simulations. Then, the Cloud part is model using real servers connected to watt-meters. In this way, it is possible to evaluate the end-to-end energy consumption of the system.

A. IoT Part

In the first place, the IoT part is composed of several sensors connected to an AP which forms a cell. It is model using the ns-3 network simulator. Thus, we setup between 5 and 15 sensors connected to the AP using WIFI 5GHz 802.11n. The node are placed randomly in a rectangle of 400m2 around the AP which correspond to a typical real use case. All the nodes of the cell are setup with the default WIFI energy model provided by ns-3. The different energy values used by the energy model are provided on Table I. These energy were extracted from previous work[1], [2] on 802.11n. Note that we suppose that the energy source of the cell nodes are unlimited and thus every nodes can communicate until the end of all the simulations.

TABLE I
Simulations Energy Parameters

(a) Wifi

Parameter	Value
Supply Voltage	3.3V
Tx	0.38A
Rx	0.313A
Idle	0.273A

(b) Network

Parameter	Value
Idle	1J
Bytes (Tx/Rx)	3.4nJ
Pkt (Tx/Rx)	192.0nJ

As a scenario, sensors send to the AP packets of 192 bits that include: **1)** A 128 bits sensors id **2)** A 32 bits integer representing the temperature **3)** An integer timestamp representing the temperature sensing time. The data are transmitted immediately at each sensing interval I varied from 1s to 60s. Finally, the AP is in charge of relaying data to the cloud using the network part.

B. Network Part

The network part represents the network starting from the AP to the Cloud excluding the server. It is also model into ns-3. We consider the server to be 9 hops away from the AP with a typical round-trip latency of 100ms from the AP to the server. Each node from the AP to the Cloud is assume to be network switches with static and dynamic network energy consumption. ECOFEN [3] is used to model the energy consumption of the network part. ECOFEN is a ns-3 network energy module for ns-3 dedicated to wired network energy estimation. It is based on an energy-per-bit model including static consumption by assuming a linear relation between the amount of data sent to the network interface and the power consumption. The different energy values used to instantiate the ECOFEN energy model for the network part are shown in Table I(b) and come from previous work [4].

C. Cloud Part

Finally, to measure the energy consumption of the server, we used real server from the large-scale test-beds Grid5000 (G5K). In fact, G5K has a cluster called Nova composed of several nodes which are connected to watt-meters. In this way,

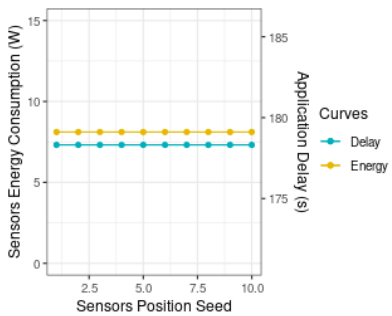

Fig. 1. Effects of sensors position on the application delay and the sensors energy consumption in a cell of 9 sensors.

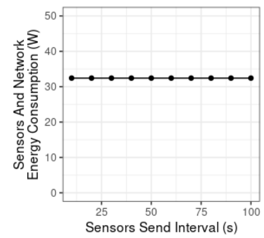

Fig. 2. Sensors send interval and its influence on the IoT/Network part energy consumption.

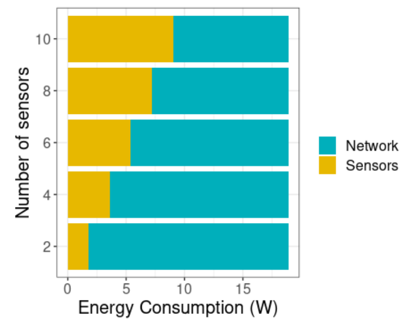

Fig. 3. Analysis of the variation of the number of sensors on the IoT/Network part energy consumption.

we can benefit from real energy measurements. The server used in the experiment is composed of Intel Xeon E5-2620 processor with 64 GB of RAM and 600GB of disk space on a Linux based distribution. This server is configured to use KVM as virtualization mechanism. We deploy a classical Linux x86_64 distribution on the Virtual Machines (VM) along with a MySQL database. We different amount of allocated memory for the VM namely 1024MB/2048MB/4096MB to highlight its effects on the server energy consumption.

The sensors requests are simulated using another server. This server is in charge to send hundred of requests to the VM in order to fill the database. Consequently, it is easy to vary the different requests characteristics namely: **1)** The number request, to virtually add/remove sensors **2)** The requests frequency.

V. Evaluation [3 col]

A. IoT/Network Consumption

In a first place, we start by studying the impact of the sensors position on their energy consumption. To this end, we run several simulations in ns-3 with different sensors position. The results provided by Figure 1 show that sensors position have a very low impact on the energy consumption and on the application delay. It has an impact of course but it is very limited. This due to the fact that in such a scenario with very small number of communications spread over the time, sensors don't have to contend for accessing to the Wifi channel.

Previous work [2] on similar scenario shows that increasing application accuracy impact strongly the energy consumption in the context of data stream analysis. However, in how case, application accuracy is driven by the sensing frequency and thus the transmit frequency of the sensors. In this way, we vary the transmission frequency of the sensors from 1s to 60s. Figure 2 present the effects of the sensors transmission frequency on the IoT/Network part energy consumption. In case of small and sporadic network traffic, these results show that with a reasonable transmission frequency the energy consumption of the IoT/Network if almost not affected by the variation of this frequency.

The number of sensors is the dominant factor that leverage the energy consumption of the IoT/Network part. Therefore, we varied the number of sensors in the Wifi cell to analyze its impact. The figure 3 represents the energy consumption of each simulated part. It is clear that the energy consume by the network is the dominant part. However, since the number of sensors is increasing the energy consume by the network will become negligible face to the energy consume by the sensors. In fact, deploying new sensors in the cell do not introduce much network load. To this end, sensors energy consumption is dominant.

B. Cloud Energy Consumption

In this End-To-End energy consumption study, cloud account for a huge part of the overall energy consumption. According a report [5] on United States data center energy usage, the average Power Usage Effectiveness (PUE) of an hyperscale data center is 1.2. Thus, in our analysis, all energy measurement on cloud server will account for this PUE.

1) Virtual Machine Size Impact:

C. End-To-End Consumption

VI. Discussion [1 col]

VII. Conclusion [1 col]

VIII. References [1 col]

References

[1] D. Halperin, B. Greenstein, A. Sheth, and D. Wetherall, "Demystifying 802.11n Power Consumption," p. 5.

[2] Y. Li, A.-C. Orgerie, I. Rodero, B. L. Amersho, M. Parashar, and J.-M. Menaud, "End-to-end energy models for Edge Cloud-based IoT platforms: Application to data stream analysis in IoT," *Future Generation Computer Systems*, vol. 87, pp. 667–678, Oct. 2018. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S0167739X17314309

[3] A. C. Orgerie, L. Lefèvre, I. Guérin-Lassous, and D. M. L. Pacheco, "ECOFEN: An End-to-end energy Cost mOdel and simulator For Evaluating power consumption in large-scale Networks," in *2011 IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks*, Jun. 2011, pp. 1–6.

[4] B. F. Cornea, A. C. Orgerie, and L. Lefèvre, "Studying the energy consumption of data transfers in Clouds: the Ecofen approach," in *2014 IEEE 3rd International Conference on Cloud Networking (CloudNet)*, Oct. 2014, pp. 143–148.

[5] A. Shehabi, S. Smith, D. Sartor, R. Brown, M. Herrlin, J. Koomey, E. Masanet, N. Horner, I. Azevedo, and W. Lintner, "United States Data Center Energy Usage Report," Tech. Rep. LBNL–1005775, 1372902, Jun. 2016. [Online]. Available: http://www.osti.gov/servlets/purl/1372902/