Pratyush Agnihotri, Manisha Luthra, Miguel Rodriguez, Boris Koldehofe. IoT-Opt: The Swiss Army Knife to Model and Validate the Performance of IoT Products.
In the Proceedings of 23rd International Middleware Conference Demos and Posters, pp. 13–14, ACM press

IoT-Opt: The Swiss Army Knife to Model and Validate the Performance of IoT Products

Demo Abstract

Pratyush Agnihotri
axxessio GmbH, Technical University of Darmstadt

Manisha Luthra
Technical University of Darmstadt

Miguel Rodriguez
Deutsche Telekom AG, Bonn

Boris Koldehofe
University of Groningen

ABSTRACT

Building an IoT solution is a highly time-consuming, costly and complex task that requires several iterations of prototyping to find and evaluate a large set of hardware and software configurations that can optimize the IoT product's performance, e.g., energy consumption of the device. Furthermore, a wide range of hardware and software configurations for different IoT solutions easily become hard to analyze and maintain.

In this paper, we present our industry solution called IoT Solution Optimizer (IoT-Opt) that helps to efficiently model and validate the performance of *any* proposed or deployed IoT products within a few minutes. The core idea is the *digital twin* technology that allows users to quickly assess implementation choices of IoT devices and model the effect of various deployment characteristics such as mobility, on their design and choose to optimize the communication efficiency or battery life performance. This innovative and powerful performance modeling capability helps enterprises accelerate their time-to-market, avoid unnecessary prolonged field trials and thereby reduce project costs. Simply put, IoT-Opt is the industry's most powerful middleware that is used by various IoT commercial products to deploy their solution.

CCS CONCEPTS

• **Computer systems organization** → **Real-time systems**.

KEYWORDS

Internet of Things, Digital twins, Smart city solution optimizer

1 INTRODUCTION

Motivation. The Internet of Things (IoT) is an increasingly important technology field for companies in nearly all sectors around the world. Its deployment consists of a network of smart but often resource-constrained IoT objects, with sensing and actuation capabilities that empower a wide range of applications in smart cities, healthcare, and homes [3]. IoT enables the users to make informed decisions with the assistance of these smart IoT objects by collecting and analyzing contextual information on environmental conditions and user behavior. However, building an IoT solution with the help of smart yet resource-constrained devices is not an easy task. This is because of the iterative process that requires multiple optimization rounds of performance evaluation, re-engineering and optimization of multiple solutions before their deployment in the real world. Therefore, productization – from the proof of concept stage to the commercialization of a usable IoT solution – is an incredibly time-consuming and complex process. In the end, small mistakes can undermine the whole business case or, in the worst case, compromise the IoT usecase's functionality.

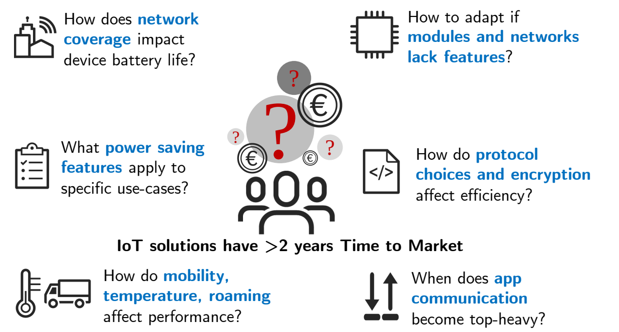

Figure 1: Challenges in the design and deployment of an IoT solution.

Furthermore, optimizing IoT solutions need experts from different backgrounds – from the hardware to application developers and network experts – to work together and raise challenges as illustrated in Figure 1. For instance, to build an IoT solution, developers need to think about multiple elements such as (1) sensors, (2) security protocol, (3) coverage area, (4) temperature impacts on the battery capacity, (5) frequency of communication and protocol behavior, (6) battery technology to be used, (7) average traffic per connection, (8) mobile network provider, and many more such features, to develop an optimized IoT solution. The lack of available performance benchmarking and planning tools in the industry that can model these elements, further aggravates the problem. Thus, an important question we ask in this paper is *how these elements work together and impact the battery lifetime.*

Contributions. We propose a novel industry-grade middleware that aids in designing a *fast* and *cost-optimal* solution for IoT applications. At the core of our architecture is an IoT Solution Optimizer (IoT-Opt) that leverages *digital twin modeling* technology, which allows the users to compose their own IoT usecase and analyze it within a *few* minutes, essentially accelerating a lengthy process that can take atleast *two years* in the real-world [4]. Specifically, we propose a solution for the optimization of NarrowBand IoT (NB-IoT) and LTE-M devices, with an aim to generate optimal configurations that enables the users to optimize the device's battery life and ensure better performance throughout the lifecycle of the IoT usecase. In addition, the IoT-Opt platform offers the users to either benchmark pre-integrated, commercially available IoT products specific for their usecase or compose their own solution by selecting components, specifying application aspects, and optimizing these for their deployment networks. The IoT-Opt provides a documentation library referred to as *"Technology Cards"* so that users can explore hundreds of IoT topics to gain insights into key technology concepts and their implementation, thereby making a more informed decision to prepare their IoT solution.

Pratyush Agnihotri, Manisha Luthra, Miguel Rodriguez, Boris Koldehofe. IoT-Opt: The Swiss Army Knife to Model and Validate the Performance of IoT Products. In the Proceedings of 23rd International Middleware Conference Demos and Posters, pp. 13–14, ACM press

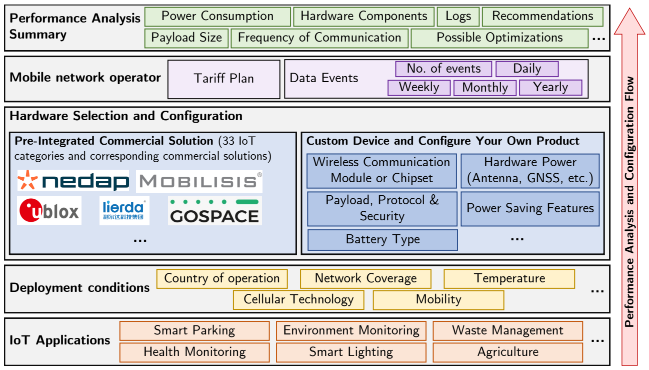

Figure 2: IoT-Opt architecture overview.

2 IOT-OPT: ARCHITECTURE OVERVIEW

IoT-Opt assists users in overcoming the aforementioned challenges in Figure 1 by modeling IoT applications and corresponding M2M/IoT devices (with an emphasis on resource-constrained devices). The user can either use pre-integrated devices or create own custom device and configure by selecting components and specifying software characteristics. Next, we provide an overview of the IoT-Opt architecture followed by a system workflow providing how users can configure *new* IoT projects but also choose from existing ones from our database.

We illustrate the high-level architecture of IoT-Opt in Figure 2 and explain as follows. Users can start building their IoT use case in IoT-Opt by selecting from the available IoT use case domain that best explains their IoT product, e.g., health, etc., and specify the corresponding deployment aspects related to the hardware, which are pre-configured in IoT-Opt. A major aspect of IoT-Opt here is the use of the digital twin modeling technique, which essentially represents a virtual model of the physical IoT device spanning its lifecycle, and is continuously updated with the real-time data of the device. Thus, IoT-Opt can monitor several indicators of the device and use this information to optimize IoT solutions. Moreover, IoT-Opt design is based on a layered distributed approach to achieve a seamless scalability and on-the fly integration of new hardware and corresponding configuration without disrupting the performance analysis at different vendors (cf. figure). This characteristic allows the system to grow and cover the needs of various IoT applications.

Another key difference we make by providing IoT-Opt is the system performance by ensuring high modeling accuracy of upto 90% in our solution leveraging our patented technology [1, 2]. We achieve this by explicitly modeling all the relevant 3GPP procedures in detail with meticulous power measurements on each IoT device. At the same time, we capture sufficient granularity of the network configuration to model the impact of all of the power-saving features (and lack thereof), as well as the communication of varying payload sizes and signal quality. Moreover, we capture data from battery and antenna supplier laboratories to model temperature and efficiency effects accurately and we model the communication handshake behavior of all major protocols like TCP, MQTT, etc. We maintain this information in the industry's largest database on chipset and modules measurements that gives IoT-Opt deep insights from thousands of customer projects we currently host. Collectively, this gives us a high accuracy in the performance benchmarks we deliver that distinguishes us from the existing limited platforms. Finally, using IoT-Opt, each project of the user can extract a *project summary report* of the applied configuration, performance results, and potential design optimization options from our highly accurate benchmarking.

3 IOT-OPT: SMART PARKING USECASE

In the following, we provide an overview of one use case of smart parking to show the capability of IoT-Opt in solving challenges mentioned in Section 1. Smart parking is a complex IoT application scenario where efficiency and performance of parking monitoring system depends on various deployment factors, e.g., the size of a parking space. Depending upon the requirements, users can choose either available parking sensors from market or develop their own hardware sensors from scratch. In both cases, currently users have no benchmarking system available where they can analyze and measure the performance of different parking sensors from different vendors or customize sensors as per their requirements as proposed in our work of IoT-Opt.

Users can use IoT-Opt to assemble a digital twin of the product they want to deploy, in this case a smart parking service. They can pick from the available countries to deploy the smart parking sensors, the access technology and other relevant hardware components from the IoT-Opt, as explained before. Afterwards other details related to the behavior and deployment aspects of the smart parking application, such as payload and protocol, power-saving features have to be specified. Once the custom design is finalized, it is used to model reliable results of expected battery life on the selected operator networks. In addition, IoT-Opt shows what aspects of the solution can be optimized to improve economic viability.

ACKNOWLEDGMENTS

This work was supported by the Deutsche Telekom, axxessio GmbH and German Research Foundation (DFG)–CRC 1053—MAKI.

REFERENCES

[1] Deutsche Telekom AG. 2020. Realistic Simulation of An Internet-Of-Things System. https://patents.justia.com/patent/20210392051. Patent No. EP18204168.1, Filed Oct. 31, 2019, Issued May 7, 2020.

[2] Deutsche Telekom AG. 2021. Method for A Simulation of the Behavior and/or the Performance of an Internet-Of-Things System. https://bit.ly/389zKzX. Patent No. EP3874685A1, Filed Oct 31st., 2019, Issued Sep. 8th., 2021.

[3] Eleonora Borgia. 2014. The Internet of Things vision: Key features, applications and open issues. *Computer Communications* 54 (2014), 1–31.

[4] Gartner. 2020. 6 Trends on the Gartner Hype Cycle for the Digital Workplace, 2020. https://www.gartner.com/smarterwithgartner/6-trends-on-the-gartner-hype-cycle-for-the-digital-workplace-2020. Accessed on 31.3.2022.