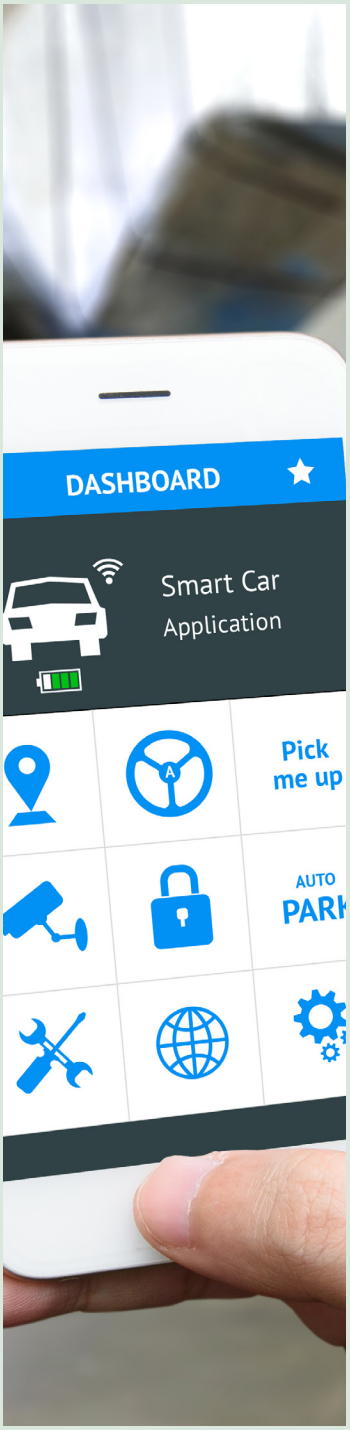
WHITE PAPER



ACCELERATING IOT SOLUTION DEVELOPMENT WITH DEVICE VIRTUALIZATION

Abstract

Internet of Things (IoT) has rapidly transformed industries and consumers, accelerating digital transformations over the last few years, bringing the physical and digital worlds together. The essential element of IoT is to build intelligent, interconnected systems that sense and act to external stimuli and environmental conditions. Such devices generate large volumes of data that need to be analyzed for information, insights, and wisdom to trigger responsive or preemptive action. The IoT-led digital transformation is being embraced across the consumer and industry verticals (healthcare, automotive, manufacturing, etc.).

The 'Things' or IoT devices are at the heart of an IoT solution. There are billions of devices connected over the internet that serve multiple industry verticals – from manufacturing to retail, to smart cities, and many more. End-to-end solution validation is a challenge in IoT solution engineering, especially on the device side. There are multiple challenges such as device availability, accessibility, and excessive cost of testing using real devices impacting the launch timelines, inadequate testing, product recalls, and in extreme cases, irreversible damage to life and property. Device virtualization is a solution that addresses the challenges by providing an abstraction to the IoT devices. The virtual devices can simulate device initialization, device-to-cloud and cloud-to-device communication, and manipulation of device configuration settings. The solution can be used for application performance testing by simulating various load and network-related scenarios. Device virtualization can effectively simulate device that are still in a prototype phase, and different generations of devices that co-exist in the system.

This whitepaper discusses the anatomy of an IoT solution, the challenges in engineering an IoT solution, the concept of device virtualization, and how it accelerates IoT platform development.

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Overview of an IoT solution

In recent years, the Internet of Things has rapidly changed the consumer and industry business landscape, enabling digital transformations across multiple segments. Billions of devices connected over the internet serve multiple industry verticals – from manufacturing to retail, to smart cities, and many more [1]. With several types of sensors available at low costs, ubiquitous network connectivity, and widespread adoption of cloud computing, IoT provides a foundation for companies to re-imagine new ways of delivering innovative products at higher efficiencies, lower costs, and in compliance with global and national regulations around parameters like emission, worker-safety, etc.

At a high level, three main components of an IoT solution can be identified: the device, connectivity, and the application that processes the data. A typical IoT deployment is as indicated in Figure 1 below:

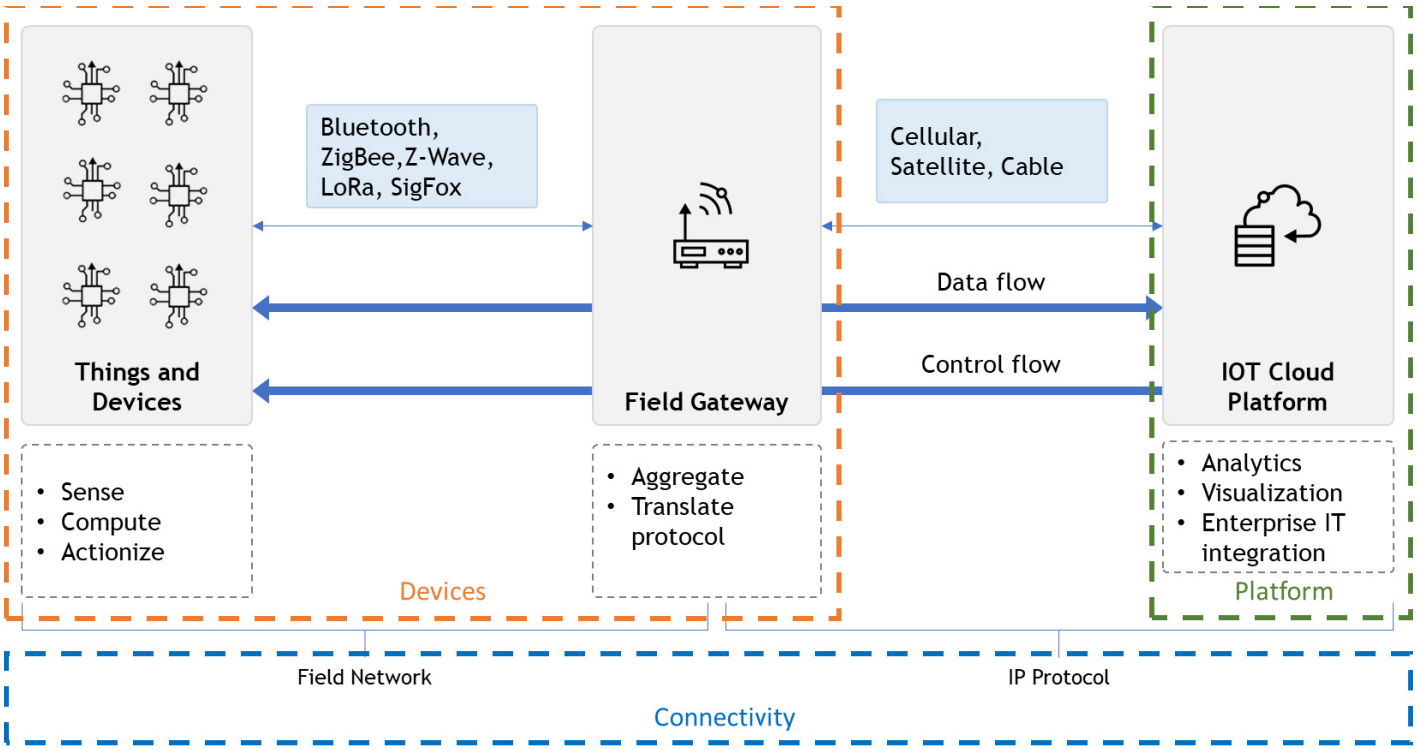

Figure 1: Main components of an IoT solution

Devices

An IoT device is a single or collection of sensors and actuators. The sensors are devices that accomplish a specific function, like sensing temperature, humidity, air quality, direction, altitude, etc. The other category of machines is the actuators that receive inputs from cloud applications and perform actions like turning off a motor or switching the focus of the sprinklers etc. These sensors must be connected to an intermediate gateway device that can transmit the data over a network to another intermediate node or directly to the cloud.

Connectivity

Connectivity refers to the connection of all points in a typical IoT ecosystem – sensors, devices, gateways, platforms, applications, and end consumer devices. This is important because connectivity enables sensed data to be streamed and aggregated in the cloud, allowing the generation of insights critical to creating new processes, products, and business models. A crucial need for IoT enablement is enabling such devices to communicate over IP to achieve cloud integration for ingestion, storage, and analytics either directly or via a gateway.

IoT platform

An IoT platform is typically a cloud platform that monitors, manages, and controls various endpoints, often via applications deployed on the platform. The IoT platform usually provides web-scale infrastructure capabilities to support basic and advanced IoT solutions and digital business operations. A basic IoT platform would have a mechanism to provision and connect with the devices, ingest device data, business intelligence for hot and cold data processing, and extensive visualization capabilities through dashboards and reports.

Lifecycle of an IoT solution

Unlike application platform development, IoT platform development introduces a high number of devices that are complex and diverse. Defining a broad and generic lifecycle of a typical IoT platform will help understand the early feedback loops that can be introduced into the different lifecycle stages that will help identify the issues early and improve the design. The IoT platform goes through the following life cycle stages – Envision, Build, Launch, Operate, and Service. There is validation in each of these stages; the objective is to shift left device validation so that the cost of quality is optimized. Every time a release is made to the field, testing is involved to ensure device and functional compatibility.

IoT Solution Validation Challenges

The IoT solution validation happens at all stages of application testing, network testing, and device testing. The business logic, analytics, and visualization elements are purely software pieces for which matured and established testing frameworks and tools are available. However, the hardware devices, their behavior on various configuration changes, their interaction with the application, and their response to commands are not as thoroughly tested. Table 1 captures the common validation strategies of the three essential IoT solution components.

IoT Solution Component	Validation Strategy
Device	• Custom simulators • Basic I/O simulation • Lab devices and prototypes • Field devices
Connectivity	• Network coverage • Load testing • Reliability testing • Network downtime testing
Platform	• Functional testing • Interoperability testing • Integration testing • Stress, Load, and Performance testing

Table 1: IoT Solution Validation Strategy

The challenge in IoT solution validation that impacts overall quality is that the actual field scenarios in terms of a combination of cases, complexity, and scale are not adequately replicated in the test environment. The key factors contributing to this are:

a) No direct access to machines

b) Limited lab testing with prototypes as against actual devices

c) Challenges in maintaining the custom simulators on par with the solution development

d) Limited load and network-related scenario emulation

e) Heavy dependency on manual testing for complex scenario-level testing

Device virtualization-based solution

An effective way to address the challenges of test coverage is to shift left device-based testing so that it replicates real-time scenarios in the field, mimics the scale of actual operation, and emulates all the potential hardware configurations and behavior. Virtualization is the logical abstraction of the underlying hardware, properties, and behavior through software implementation. Device virtualization decouples the control from hardware, and the software is used to configure, manage and upgrade [4].

The concept of device virtualization provides a feasible and practical solution by making virtual copies of the physical devices available. The degree of virtualization may vary from device replicas that simulate the I/O behavior of the devices to complex digital twins that try to emulate the machine's functioning. For validating the IoT platform, it would suffice that these virtual devices can simulate the I/O operations of the actual devices, adjusting to the device configuration changes. The critical factor is to create this virtual device and replicate a million copies of it to match the real-world scenario.

The Hyperscaler provides IoT Device Simulators as tools that can be used to test device integration and improve performance. AWS and Azure refer to it as IoT Device Simulator [6], [7], whereas Oracle refers to it as Device Virtualization [5]. There are other solutions, such as IoTify, and HiveMQ Swarm, available in the market [8]. Based on an analysis of all these solutions, the key features of an end-to-end device virtualization solution are –

a) Simulation of device I/O behavior, including the support for different messaging protocols

b) Ability to scale to the tune of a million devices

c) Control each simulated device independently

d) Ease of configuring the parameters and modifying the values

e) Mechanism for comprehensive security testing at the hardware layer – authentication mechanism, open ports, secure boot, etc.

f) Simulate devices using actual device firmware

g) Support for unstructured data like audio, video, images

h) Test automation and integration to existing test infrastructure.

The benefits of device virtualization are articulated in Figure 2.

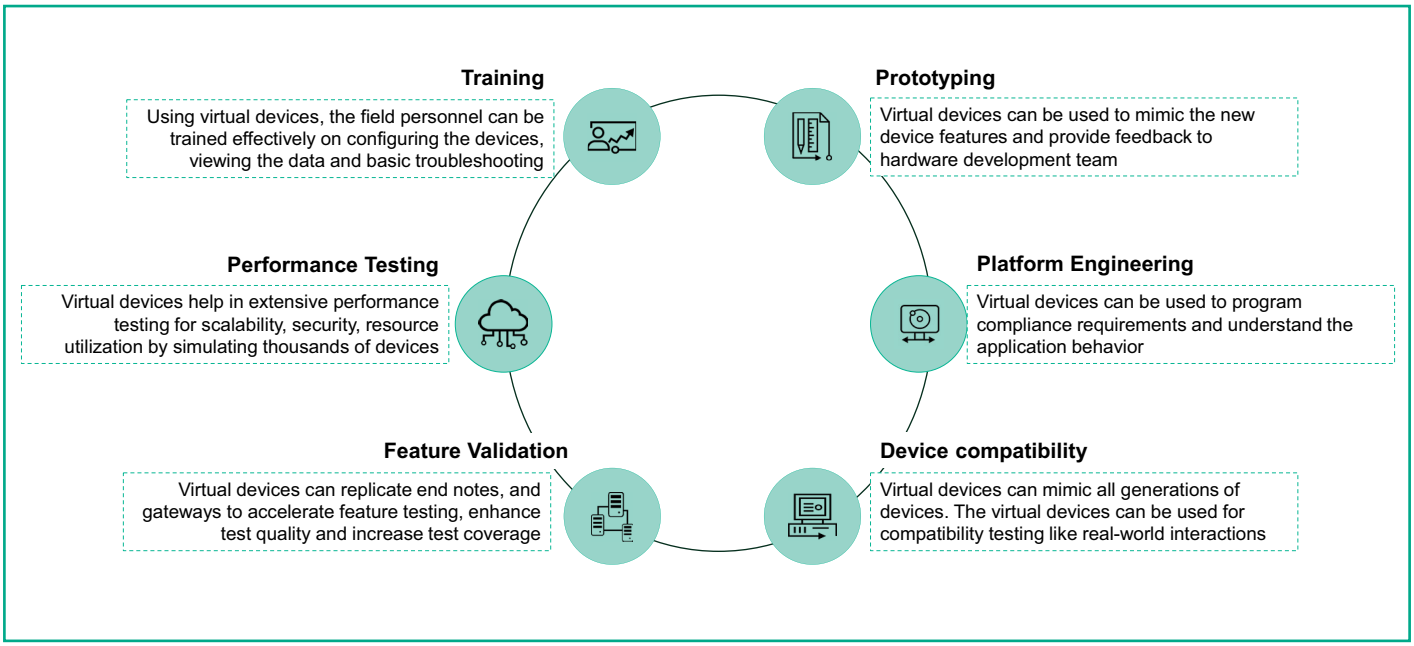

Figure 2: Device Virtualization benefits

Infosys has a three-pronged approach to developing device simulation solutions; depending on the client context and various other factors, the best-fit solution is considered.

a. Our expertise in developing custom simulators

b. Deploying Infosys device simulator solution (our Intellectual Property)

c. Partnership with low code IoT validation platform – Doppelio

The decision to leverage a custom simulator or use a SaaS-based solution is context-dependent and depends on multiple parameters, as shown in Table 2. The decision matrix is a guide and, based on the specific context, would have to be enhanced as required. The subsequent sections discuss Infosys Device Simulator and the Doppelio platform in detail.

	Feature Fitment	Ownership	Maintainability/ Support	Scalability	Total Cost of Ownership	Time to Market
Custom-built Device Simulator						
Commercial Off the Shelf Platform						

Low High

Table 2: Custom Simulator vs. Off-the-shelf platform Decision Matrix

Infosys Device Simulator

Infosys Device Simulator is a platform agnostic simulator that works with standard and custom IoT platforms. The solution provides a single pane of glass to configure, plan, run IoT tests and view the reports. The critical features supported are:

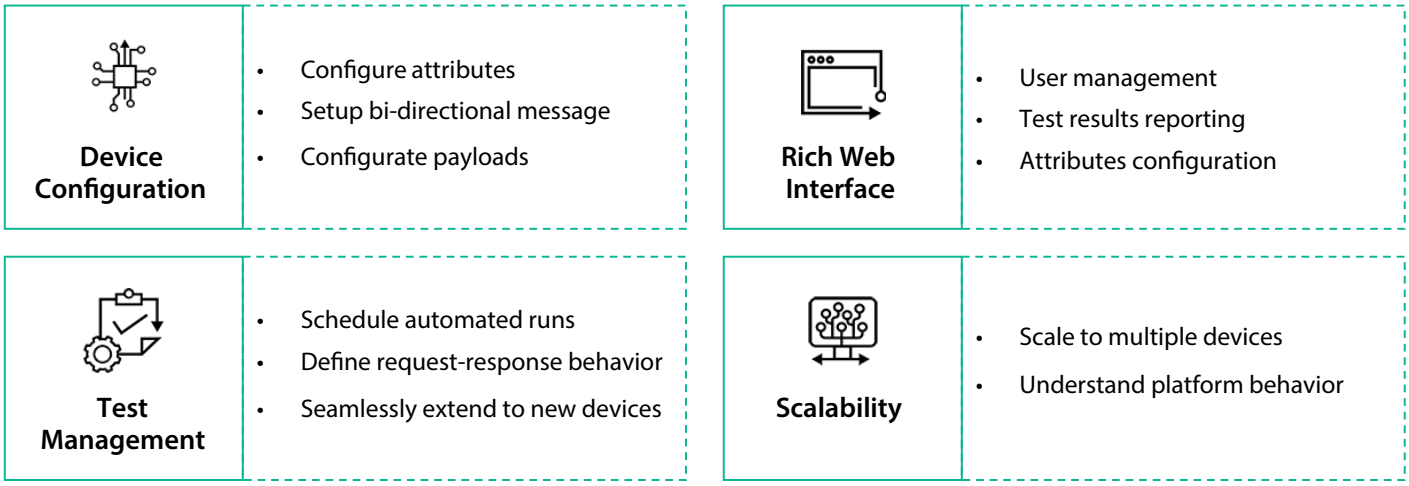

Figure 3: Key features of Infosys Device Simulator

The device simulator is developed using the Kubernetes service. The solution can containerize and deploy multiple simulated devices to simulate real-life scenarios of thousands of active connections to test how the platform responds to high loads.

Infosys Device Simulator was used to successfully simulate next-generation hardware and its behavior when there was a significant delay in the hardware engineering team. The simulation ensured the platform team continued the development. Device communication issues were identified early in the life cycle, and the feedback on platform behavior was critical to the hardware engineering team as they progressed on the design. Using the Infosys Device Simulator, the following benefits were delivered:

a) Lab test coverage increased from 60% to 85% using different device configurations

b) Performance testing by simulating devices helped increase IoT solution performance by ~15%.

c) Load testing helped resolved critical issues before launch.

d) Aided business decisions on using PaaS components by comparing performance metrics.

Doppelio – Test Automation Platform

Few cloud-based standard code platform solutions offer end-to-end IoT validation capabilities [3]. The AWS and Azure device simulators are an example that provides a basic framework for creating devices and manipulating the IO properties. Infosys has partnered with a company named Doppelio that offers complete data simulation and firmware emulation capabilities.

Virtual Devices

- Device parity
- Assemble as System Of Things
- Emulate gateway and edge devices

Low Code Automation

- Orchestrate end-to-end test scenarios
- Create once and run on-demand
- Extensible template-based device configuration

Data Simulation

- Unlimited scenarios
- Data parity with real world environments
- Firmware update verification

Test Infrastructure

- Seamless test infrastructure scaling
- Pay-as-you-go pricing model
- Integrate into the CI-CD pipeline

Figure 4: Key features of the Doppelio Platform

Doppelio is a low code automation platform that integrates into the client's existing environment. The platform simulates the Data I/O of the devices; these can be configured based on message protocol and frequency and assembled as a system of things. In addition, edge devices can be simulated in the same constrained environment as in real life. Through a combination of data doppels and VM doppels, the platform reduces the overall risk because of devices, increases the time to market, and lowers the cost of quality. Infosys solution leverages the Doppelio platform and associated services to set up, configure and integrate into the client's testing environment.

Conclusion

Digital transformation has become inevitable to any business across domains. IoT technologies play an integral role in these transformations. Industries have moved on from "the trial stage to full-scale adoption." As the number and complexity of smart things increase, the engineering and infrastructure to support and enable IoT solutions also grow. IoT solution validation is a critical life cycle activity and is complex because of the devices involved. There are multiple challenges such as lack of physical device availability, expensive to test with real devices in the field, and ability to simulate load conditions. Simulation testing based on device virtualization is an effective solution to address these challenges.

The key benefits of device virtualization - simulating multiple versions of the hardware, scaling to millions of virtual devices, simulating unreliable network scenarios, verifying device commands and features like Firmware Over The Air (FOTA) will help save time and effort while improving quality tremendously. It will also reduce the post-launch service costs significantly, thus, enabling businesses to get more out of their digital transformation initiatives and new business models. Enterprises need to decide between building a custom simulator or using SaaS-based solutions. Infosys has a multi-pronged strategy to address the client needs around IoT solution validation.

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