Developing IoT Solutions with
Azure IoT Hub Platform

An IoT solution monitors large volumes of devices in real time, processes large volumes of messages, provide inputs for intelligent decision making, predicts, prevents or alerts potential failure situations using Artificial Intelligence and also provides for storing processed data for future analysis.

Full featured IoT solutions can be developed on Azure® Cloud Infrastructure leveraging Azure IoT Hub and various other Azure cloud services. Azure IoT Hub enables the development of highly scalable, secure, cost effective and globally redundant solutions to cater to varied business requirements.

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Introduction

Internet of Things (IoT) platform is the supporting software that connects devices, networks, and end-user applications. It enables IoT applications involving provisioning, connectivity, monitoring, and automation of connected devices from diverse sources.

Among the several IoT platforms in the market today, Azure IoT Hub offered by Microsoft® stands out due to its feature-rich portfolio and significant customer base. Azure IoT provides "Platform as a Service", which enables billions of devices to securely interact with themselves as well as applications residing on cloud.

In this white paper, we analyze the different building blocks of an IoT platform and how Azure IoT Hub realizes those blocks through its managed services. We examine the various services provided by Azure IoT Hub to build connected devices solutions, integrating other services provided by Azure for device onboarding, message ingestion, storage, analytics and third-party integration.

IoT Platform

An IoT platform is the key to the development of scalable and secure IoT solutions and services. For developers, an IoT Platform provides a ready-to-use scalable and secure platform, which can help in the faster development of IoT applications and the services underneath for connected devices.

Components

A true, end-to-end IoT platform consists of the following high-level building blocks.

- **Connectivity**: Provides one single software interface to collect data from diverse connected devices communicating different protocols and data formats.
- **Fleet Management**: Provides provisioning, configuration and software/firmware updates functionality on devices and edge gateways.
- **Storage**: Brings scalable storage, which can handle the volume, variety, velocity and veracity of billions of messages from connected devices.

- **Rule Processing**: Triggers actions against incoming messages based on configured rules. It can also route messages to configured destinations.
- **Analytics**: Derives insights from the IoT data-stream by doing a range of analytics from simple aggregation to predictive analytics, anomaly detection and other machine learning algorithms.
- **Visualization**: Provides tools to visualize IoT data in the form of various charts. This enables human operators to derive meaningful outcomes from patterns and trends.
- **External Interfaces**: Enables end-to-end operations of the IoT systems with business connectors that integrate the underlying functionality of the IoT platform tier with business functions including ERP, CRM, service lifecycle management, billing and payment, work planning and scheduling systems.
- **Development & Test Tools**: Provides stacks and libraries for interacting with the IoT platform to rapidly build prototypes and products.

Reference Architecture

A typical IoT architecture has several components that interact with each other to collect data from IoT devices, process them and store the data.

Devices communicate with the IoT infrastructure directly, if they are capable or via a field gateway commonly referred to as Gateway. A single gateway can collect data from one or more devices and securely send/receive data from the cloud IoT infrastructure.

A Device Gateway on the cloud side facilitates secured data communication between devices/gateways and cloud IoT servers. The Device Registry stores the device information and maintains the state and device data in it. Stream Processors ensure that large amount of input data is streamed to storage or to the analytics/machine learning engines.

Applications and different business systems can use the data available in the storage or processed by analytics and machine learning using application interfaces or business integrators to achieve different business goals.
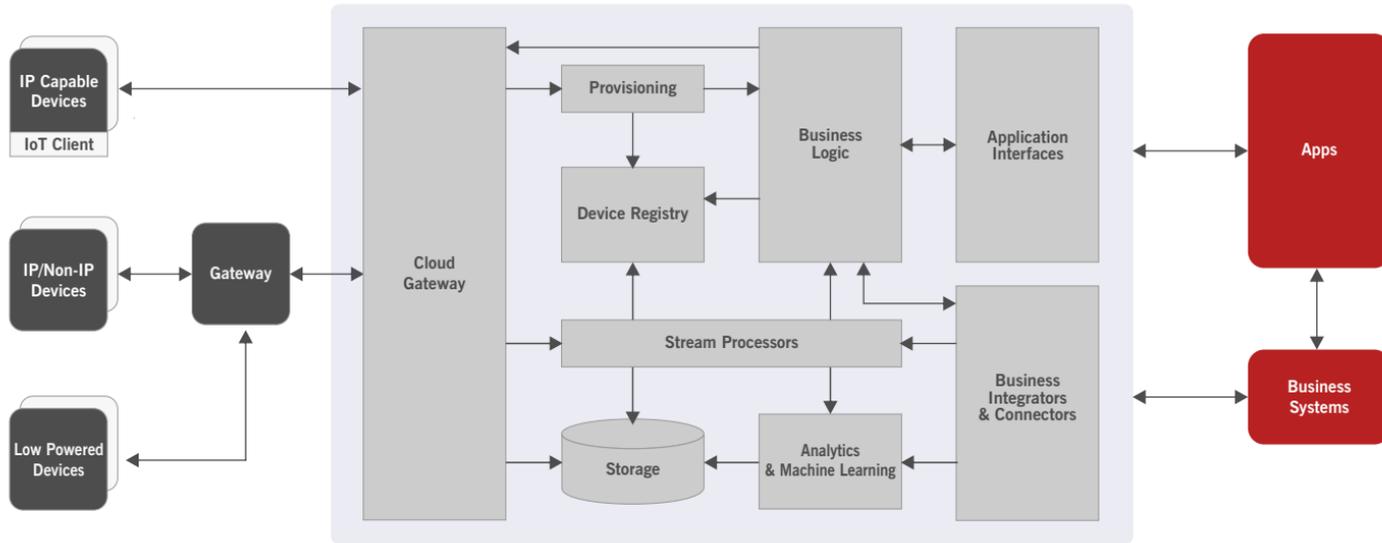
Figure 1. Typical IoT Reference Architecture

Azure IoT Hub Platform

Azure provides several cloud services and SDKs to build end-to-end IoT solutions catering to various real life situations. These services and SDKs empower developers to enable IoT for devices, capture device telemetry data on cloud, run near real-time analytics, trigger alerts, and integrate with external applications, store data and run real time anomaly detection or predictions based on machine learning models.

Components

The two critical aspects of developing a connected device cloud solution involves:

- Enabling the device to connect to the cloud and onboarding it.
- Building the IoT solution on the cloud for the specific business scenario.

Azure IoT Device SDKs enable developers to build applications that run on the IoT device. These devices can send telemetry messages to the Azure IoT Hub or Azure Event Hub through the application. The edge devices can also receive messages, jobs or twin updates from the Azure IoT

Hub. Azure device SDKs are available in C, .NET, Java®, Node.js, Python® and also for iOS®. Higher powered devices on the edge can also run Azure IoT Edge stack to do real-time analytics.

The most important and primary Azure cloud service required to build an IoT solution is Azure IoT Hub. The other Azure services like Stream Analytics, Time Series Insights, Azure Storage or Cosmos DB receive telemetry information from Azure IoT Hub for further processing. Development of Web applications and other Azure cloud integrated applications is done by integrating Azure IoT Services SDK.

Azure IoT Hub: Azure IoT Hub enables bi-directional communication with IoT devices. It can handle millions of device-to-cloud telemetry messages and define message routes to other Azure services. It can also reliably send cloud-to-device messages, send notifications to devices, and also handle intermittently connected devices. Azure IoT Hub can provide per-device authentication and automatic device provisioning and registration. Azure IoT Hub maintains a Device Twin for every device connected. It stores device state information including metadata, conditions and configurations. It supports native communication over the MQTT, AMQP, and

HTTPS protocols. Devices or field gateways can use one of these standard protocols to communicate with IoT Hub. In some cases, a custom gateway is used to enable protocol adaptation for IoT Hub endpoints.

Azure Stream Analytics: Azure Stream Analytics is an event-processing engine that enables IoT solutions to analyze high volume streaming data received from edge devices, sensors, apps, social media, web sites, etc. It uses SQL-like queries to process data streams. It can extract information, identify patterns and relationships in the data, and do analytics in near real-time based on time-sliced streaming data. These analytics can be used to trigger downstream actions for various other Azure services.

Azure Digital Twin: Azure Digital Twin is a virtual or digital representation of a process, product or service. It helps to model and create digital representations of connected environments with an open modeling language called Digital Twins Definition Language (DTDL) and gain insights into devices, products, services and environments. In the IoT world, Azure Digital Twin can represent the device digitally and is driven with data from IoT devices. The Azure digital twin represents the

structure and the behavior of the device by capturing real-time data and can be used to monitor the device.

Azure Sphere: It is a comprehensive security solution for IoT devices. Azure Sphere fortifies IoT devices using Azure Sphere certified Microcontroller (MCU) chips, Azure Sphere OS and the cloud components. The Azure Sphere OS is a custom Linux® based microcontroller operating system to run on an Azure certified chip and connect to the Azure Sphere Security Service. The Azure Sphere Security Service is a cloud service which guards every Azure Sphere device by certificate based authentication for device-to-device communication and device-to-cloud communication, provide software updates and online failure reporting.

Azure RTOS: Azure RTOS is a real-time operating system (RTOS) for IoT and edge devices powered by MCUs and designed specifically for embedded applications. The Azure RTOS platform is the collection of run-time solutions including Azure RTOS ThreadX® (OS), Azure RTOS FileX (File System), Azure RTOS GUIX (User Interface), Azure RTOS NetX (Network Connectivity), Azure RTOS NetX Duo (Network Stack), and Azure RTOS USBX (Interface for USB

devices). Azure RTOS is pre-certified for a variety of safety standards and is available on Azure Sphere devices.

Azure Cosmos DB: Azure Cosmos DB is a globally-distributed, limitless scaling, multi-model database with guaranteed low latency. It offers key-value, graph, column-family and document data in one service using API interfaces for MongoDB®, Azure DocumentDB, Apache Cassandra®, Gremlin and Azure Table Storage.

Azure Web Apps: Azure Web Apps is a PaaS for developing and hosting Web applications on Azure without managing infrastructure. It provides a highly secure environment, with load balancing, auto-scaling and high availability. It supports both Windows® and Linux, and also has inbuilt DevOps capabilities like continuous deployment from various sources, package management, staging, custom domain and SSL support.

Azure Notification Hub: Azure Notification Hub is a highly scalable mobile push notification engine. It can send millions of notifications to iOS, Android, Windows or Kindle devices.

The major services supported are the Apple® Push Notification service (APN), Google™ Cloud Messaging (GCM), Windows Push Notification Service (WNS), and Microsoft Push Notification Service (MPNS). Notifications to specific customers or audiences can be tailored with a few lines of code.

Azure Logic App: Typical IoT solutions require integration with third-party software systems to push analytics data or to invoke workflows based on events. Workflows can be developed to achieve this integration across enterprises by automating tasks and business processes. Azure Logic Apps can be used to simplify the design and creation of solutions for app integration, system integration, data integration, EI (Enterprise Integration), and B2B communication.

Azure Machine Learning: Microsoft provides Azure Machine Learning Studio to build, test and deploy solutions for predictive analytics on data. It can publish models as Web services which can be integrated or consumed by IoT solutions or other BI Tools.

Solution Architecture

Azure IoT Hub provides a complete ecosystem for IoT solutions and provides multitude of services for stream processing, storage, analytics and machine learning. Figure 2 illustrates how different Azure services can be used together to achieve a full-fledged IoT application that collects data from devices stores, analyses and apply machine learning.

Azure provides IoT Device SDK which enables IP devices to connect to Azure IoT Hub directly. Azure Edge or a Field Gateway can be used to connect non connected device(s) or a group of connected devices to Azure IoT Hub using a protocol that is supported by Azure IoT Hub. Azure IoT device gateway authenticates and authorizes devices messages and stores state of the device in Device Twins. Azure Stream Analytics encrypts the data to a suitable format for storage systems such as Azure Blob storage, Azure SQL Database, Azure Data Lake Store, and Azure CosmosDB. Azure Logic Apps provides various built in connectors to integrate into different business systems.
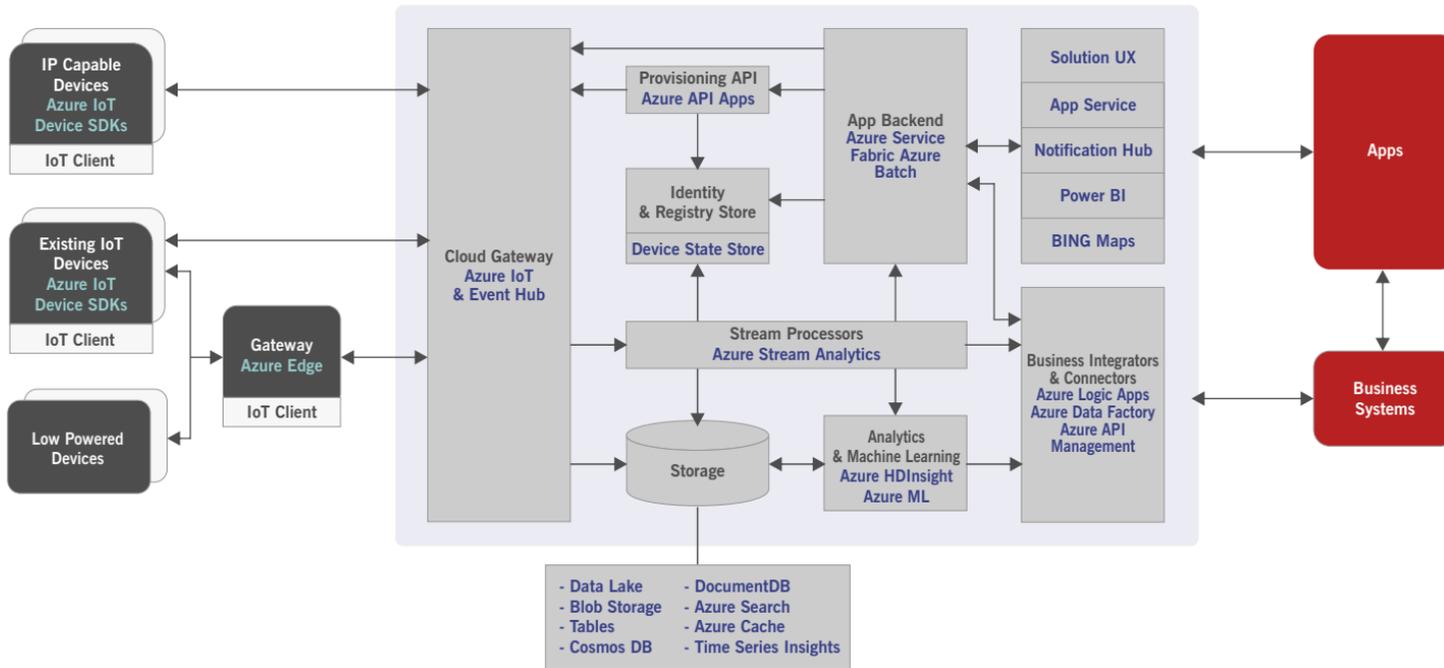
Figure 2. Azure IoT Hub Architecture

As a leading IoT platform, Azure IoT Hub provides a host of services to build sophisticated IoT solutions, with a wide choice of alternatives for specific business requirements. For example, for cost optimization, the Cosmos DB could be replaced with Azure Storage Services, but with an impact on latency. Further, Azure Stream Analytics needs to be used only when there is a need for near real-time data analytics for taking specific actions based on a situation. Similarly Azure IoT Solution Accelerators (refer page xx) can also be customized and optimized based on specific business scenarios.

Figure 3 shows a typical IoT solution built using Azure IoT Hub and some of the alternatives shown above.

- The devices on the edge are integrated to Azure IoT Hub directly, or through the Azure IoT Edge device.
- Azure cloud layer, which consists of Azure services configured to work together based on the IoT solution requirements.
- Application layer comprising End-user and Administrator Applications, Business Intelligence Apps, Mobile Apps.
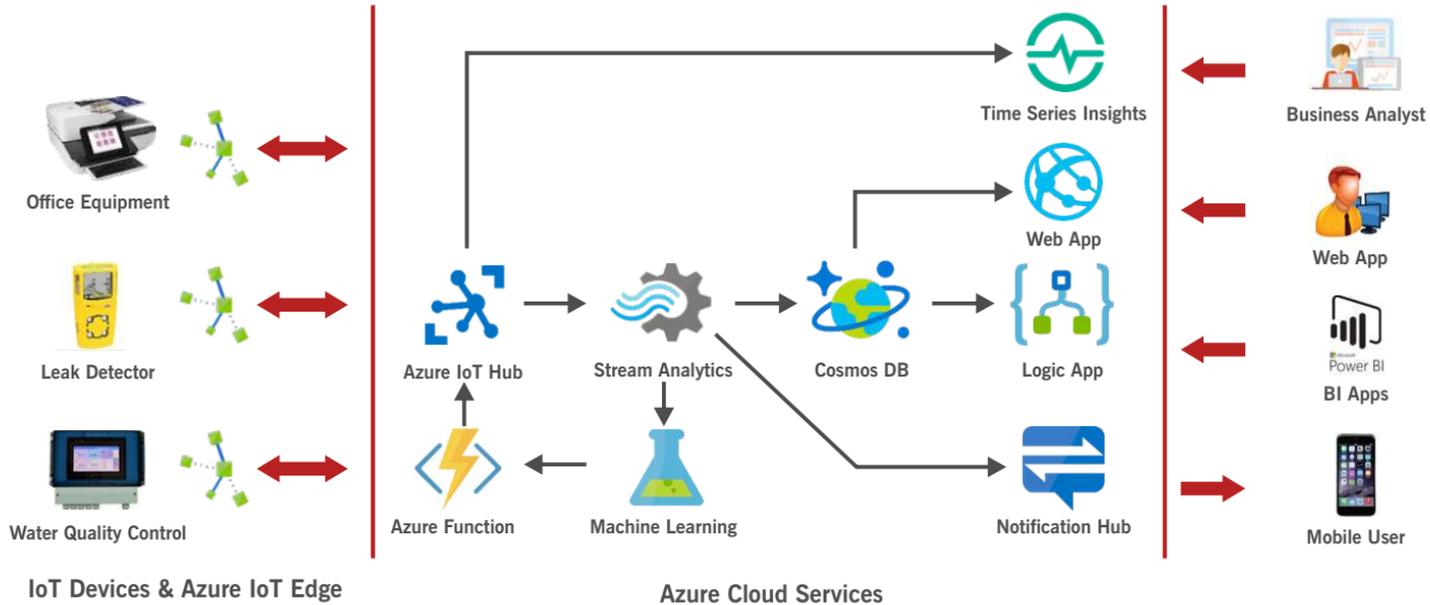
Figure 3. Typical Azure IoT Hub Solution

Solution Enablers

Azure IoT Solution Accelerators: Azure IoT Solution Accelerators are ready-to-deploy, complete IoT solutions for common IoT scenarios. They provide the core implementation, which can further be customized for the real business case, and optimized for cost and performance requirements on the field. These solution accelerators enable quick piloting of IoT solutions, and help businesses to determine the feasibility of their business ideas for connected products and smart devices.

Currently, Microsoft offers four solution accelerator solutions:

- **Remote Monitoring**: Remote monitoring dashboard enables viewing the telemetry from the connected devices, provisioning new devices, or upgrading the firmware on connected devices.
- **Connected Factory**: Connected factory dashboard enables the monitoring and management of industrial devices.

- **Predictive Maintenance**: Predictive maintenance dashboard enables viewing predictive maintenance analytics.
- **Device Simulation**: Device simulation web app enables configuring and running simulations.

Azure IoT Central: Azure IoT Central is an industry-agnostic IoT application platform SaaS offering that reduces the burden and cost of developing, managing, and maintaining enterprise-grade IoT solutions. Microsoft hosts and supports the IoT Central application and also manages the Azure resources. There is no ability to configure/customize/remove any of the individual Azure resources used in the IoT Central application. Custom applications can be created for any type of industry. Ready to deploy application templates helps to kick start the IoT solution development. The application templates consists of operator dashboard, device templates, pre-configured rules and jobs. Some of the templates available today are for these industries:

- Retail
- Energy
- Government
- Healthcare

Pricing

Like other Azure services, the Azure IoT Hub platform too is metered on a pay-per-use model. For instance, for basic IoT functionality, prices are based on the number of messages sent/received to Azure IoT Hub.

Typical pricing for Azure IoT Hub is calculated based on the following factors:

Azure IoT Hub: The pricing model is based on the total number of messages sent/received to Azure IoT Hub per day. A message is defined as 4KB in size. Pricing is based on functionality and offered in two tiers – Basic and Standard. Within each tier, there are edition types that are based on the number of message per day and throughput. The tier can be upgraded without interrupting the existing operations.

Edge Runtime: The Azure IoT Edge runtime license is free and open-sourced under the MIT license.

Azure IoT Central: IoT Central SaaS platform pricing is based on total number of messages sent/received. A message is defined as 4KB in size. There are two tiers of pricing based on functionality – Standard Tier 1 and Standard Tier 2.

Azure Solution Accelerators: Solution Accelerator pricing is based on the solutions used. The cost of the solution is an aggregate of the underlying Azure Services used.

Conclusion

IoT comes with its own challenges of scale, diversity, connectivity, privacy, security and regulatory compliance. There are many IoT platforms which promise to deliver easily customizable software components as "Platform as a Service" to solve these challenges. These pay-per-use platforms enable the quick implementation of low-cost proof of concept IoT solutions without writing code and extension to production quality and scalable solutions, which can connect to millions of devices.

As a leading IoT platform, Azure IoT Hub provides a host of services to build sophisticated IoT solutions, with a wide choice of alternatives for specific business requirements.

As an IoT services provider, Thinxtream has delivered quality IoT solutions based on Azure IoT Hub. Thinxtream has expertise in Azure cloud services, integrating them and deploying Azure solutions using Infrastructure-as-Code and other DevOps methodologies. Thinxtream has extensive experience in customizing and deploying IoT Solution Accelerators to meet specific business requirements. By leveraging the IoT expertise built over a decade, Thinxtream ensures cost-effective, quality and timely delivery of IoT solutions.

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Thinxtream Technologies is a global software company with a portfolio of innovative software platforms, components, solutions, patents, competences and services for Internet of Things (IoT) across several industry verticals and applications, successfully enabling leading customers, including Fortune 500 companies, meet their application, product and business goals.

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