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# How to Design IoT Systems

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A quick guide to designing a perfect Internet of Things (IoT) system taking into account performance, connectivity, power consumption and security issues

The Internet of Things (IoT) is no longer a technology of the future. Smart cities, connected industries and smart households have indeed ushered in an era where machines can communicate. The beauty of this technology lies in the fact that the complex backend structure of systems is represented to the end-user in the simplest possible form. This requires profound design know-how.

## What the IoT is made up of

The IoT can be designed at different scales for different uses. It can start from our homes with simple lighting or appliance control, and expand into the realm of factories and industries with automated machines, smart security systems and central management systems—called connected factories. It has scaled up to entire cities with smart parking, smart metering, waste management, fire control, traffic management and any similar functions involved. However, irrespective of the scale of application, the main IoT backbone remains similar.

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The IoT architecture is multi-layered with delicate components intricately connected to each other. It starts with sensors, which are the source of data being collected. Sensors pass data onto an adjacent edge device, which converts data into readable digital values and stores these temporarily. When the edge senses a suitable wireless network or the Internet, it pushes the locally stored data to a cloud server involved in the application. The data is processed, analysed, stored and forwarded to the end-user device, represented by an application software. All the design fundamentals and challenges revolve around these layers.



## Designing the perfect system

Successfully setting up a complete IoT chain comes with certain challenges. Designers need to walk the extra mile to meet all business requirements like prolonged battery life and low power consumption, secured network gateways, ruggedised hardware and more. Electromagnetic compliance (EMC) and resistance to [electromagnetic interference](https://www.electronicsforu.com/tech-zone/communication-tech/electromagnetic-interference-compatibility-indian-scenario) (EMI) are also essential. Introducing new devices within a wireless radius without disturbing the existing system is one of the most demanding skills for an IoT design.

Components like the microcontroller unit (MCU), sensors and wireless network are built and handled with special care for an optimal system design. Based on the scale of application, the design is bound to alter. While basics remain the same, minute detailing into engineering improves a system build by leaps and bounds.

### Optimising the MCU

An MCU is the central nervous system of the IoT setup. Data collected by sensor nodes is processed by the MCU using software programs, enabling the system to respond accordingly. The MCU for an IoT system is chosen based on application-specific requirements.

For basic applications with limited amount of data to be transmitted every day, an 8-bit MCU will suffice. On the other hand, large-scale connected systems require 32-bit controllers. As 32-bits MCUs have a bigger RAM size and larger flash that can hold a complete network stack and application codes, these are optimal for embedded systems that will apply radio-frequency (RF) program stacks or complex algorithms.

According to Kavita Char, formerly senior product manager at Silicon Labs, MCUs with floating-point units ([FPUs](https://en.wikipedia.org/wiki/Floating-point_unit)) have further compatibility for such applications and ease the computation process. An FPU-supported controller enables precision up to long decimal values. This gives a lot of flexibility in data calculation and eliminates the requirement of overflow-checks in the program.

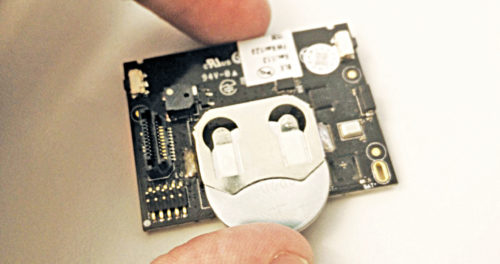
MCUs with FPUs can be of great advantage in applications like location tracking, processing of measurement data from accelerometers and gyrometers, or any application where data precision is quite important.

### Designing the connectivity module

How would you want your devices to interact? At the moment, major wireless options include Wi-Fi, Bluetooth Low Energy (BLE), GSM and Zigbee. Designers need to pay attention to some essential criteria for choosing a connectivity module. Some of these factors include data throughput, connectivity range and speed required, power requirement, scalability, robustness and upgraded protocol. Designers must choose a technology that will survive the test of time.

Building an effective connectivity model depends on two components: transceiver of the module (which essentially consists of a receiver, a transmitter and an antenna) and network frequency.

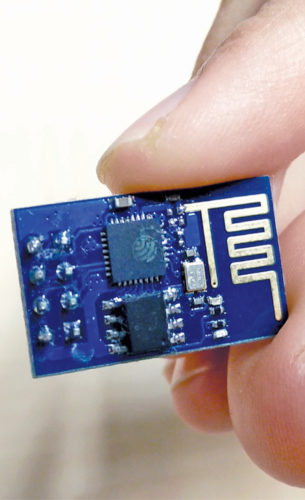
The receiver of a transceiver sets the threshold for the signal to be received and also ensures that the signal is distinguishable from the other signals in the same frequency and the ambient noise. Therefore ensuring a high-quality receiver is imperative. Lower data rate improves sensitivity of the receiver.

Coin-cell battery-driven sensor module (Image source: thingsquare.com)

The transmitter, on the other hand, controls the output power of the transceiver—how much it can amplify. Experts suggest a 6dB gain capacity can double the amplitude of the output signal. While higher transmitter power means higher output signal, there is a trade-off in battery life. Hence this decision should depend completely on the type of application, the data to be amplified and the geographic location.

Now let’s talk about the frequency, which determines the range and data-throughput capacity. For IoT applications, sub-1.0GHz and 2.4GHz are the most used frequency ranges. Unlike the large data flow during media streaming or voice/video calls, IoT applications are associated with small data packets.

Now, many developers opt for 2.4GHz frequency range owing to its popularity in mainstream applications. This frequency range does provide higher data throughput capacity but not without challenges. First, the 2.4GHz array has a lower range of coverage and poor penetration through obstacles. More importantly, this frequency has a heavy traffic of data packets coming from other devices like microwave ovens and Wi-Fi devices. This creates the problem of signal interference.

Wi-Fi IoT module (Image source: makerstream.blogspot.in)

Sub-1.0GHz range, on the other hand, offers greater coverage range and sensitivity in lieu of data volume throughput. Distributed infrastructure can greatly benefit from its long-range characteristics. Moreover, data transmission through obstacles is possible.

Char suggests, “Since sensors of an IoT system generate small data throughout the day, sub-1.0GHz frequency is suited for most applications as it consumes much less power and provides connectivity for years on a battery.”

For instance, IoT systems in agricultural fields or oil and gas industries will share very low-volume data such as soil pH, moisture level and gas level. A sub-1.0GHz frequency can efficiently cover the complete perimeter while consuming much less power.

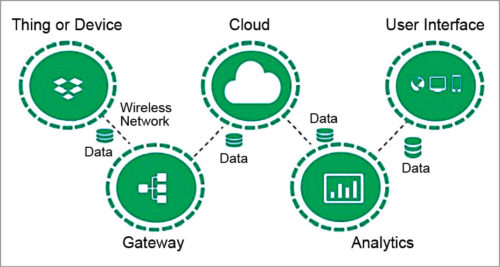
Coming to wireless standards, while 802.11ac is the most popular Wi-Fi standard in the market, a newer iteration called IEEE 802.15.4 is gaining prominence for the IoT.

### Creating a power-efficient system

For IoT applications, designers need to focus on power requirements. Batteries used in these systems are expected to last up to 20 years without requiring much manual intervention. The uniqueness of IoT design elements is their ability to sleep when not in use.

Gaurav Sareen, country head-India, Sigfox, explains, “The transceiver wakes up only when it is supposed to transmit data. As soon as it is done, it goes back to sleep. So, the hardware is essentially asleep most of the time. That is how it conserves energy.”

IoT systems consume power in two modes: dynamic (when the hardware is active) and static (when the hardware is asleep or in standby mode). It is essential to keep these factors in check. Consumption of both the MCU and the transceiver are considered. 32-bit MCUs can transmit data faster. Therefore their dynamic consumption can be much less, enabling the chip to save more energy. FPU compatibility further enhances efficiency. Large-scale applications in businesses can greatly benefit from FPU-supported MCUs.

Key IoT components to Design IoT Systems (Image source: rfpage.com)

### Software for security

Security solutions are essential to ensure that no part of the system (hardware, software or network gateway level) is compromised.

Sareen mentions, “Secure Elements (SE) are in use to ensure safety at hardware level. An SE itself is an additional hardware component that encrypts data and checks authenticity of the device receiving it. The network layer is secured by hiding the data in motion with advanced encryption schemes (AES). Data cannot be breached while being transmitted through network gateways. Finally, data itself is tested in the application layer to ensure it is infection-free.” Authentication levels, including passwords and biometrics, provide secured access to all components and data. In addition, there are debug software that ensure proper functioning of the IoT system.

## Why it’s the best time to Design IoT Systems

The job of designers is becoming even simpler with manufacturers introducing integrated modules like MCU-cum-transceiver units that facilitate quicker IoT system design. Efficient software tools allow speedy programming of embedded syste

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<https://anywhere.epam.com/business/how-to-build-an-iot-application>

Internet of Things (IoT) applications are already changing the way we function on a daily basis by relieving us from doing both simple and more complicated tasks. But that’s not all — building IoT applications is also meant to make consumers’ lives better, whether it’s the concept of a smart home or a wearable band tracking our health rate during different activities.

In short, the Internet of Things means physical devices (or groups of devices) equipped with sensors, software and other technologies, and the ability to connect and exchange data with other devices and systems via the Internet or other networks (like Wi-Fi or Bluetooth).

IoT technology has a huge impact not only on individuals but also on business and society in general. And a quick look at some stats is enough to see that impact only growing in the future. For example, [according to Statista](https://www.statista.com/statistics/1101442/iot-number-of-connected-devices-worldwide/), the number of connected IoT devices will grow from 13.8 billion units in 2021 to 30.9 billion units in 2025. It indicates that there will be more demand for IoT apps and devices, and consequently, more companies that develop them. EPAM is proud to be one of those companies.

If you are interested in building an IoT app, keep reading to learn how to do it the right way. In it, we’ll cover:

* Why startups decide to create IoT applications
* **Cost of developing small and simple IoT app**— starts from $80,000;
* **Cost of developing medium, more advanced IoT app**— starts from $100,000, up to $150,000;
* **Cost of developing an advanced app with multiple features**— starts from $150,000 and more.
* If it’s better to build web or mobile apps and why
* What tech stack you should choose for IoT development
* How to create an app for IoT that users won’t remove
* The cost of building an IoT app in 2022
* Building IoT apps with enterprise-level experts like EPAM Anywhere Business

## Areas with the biggest demand for IoT applications

IoT solutions impact not only the lives of individuals but also society in general. What are some of these impacts? First of all, think about a smart home concept (or smart city in the broader sense), biometric scanners, wearable health monitors, voice assistants (like Siri) or smart cars (like Tesla). All of these examples of IoT are making a huge difference to the way we live, work, eat, train, and function in general.

IoT has a variety of applications and offers many possibilities. Here, we describe just a few of them, those with the biggest demand and highest potential return on investment in development.

We’ve also added relevant examples of successful startups in the IoT industry together with opportunities that each particular niche offers. You can treat it as inspiration to learn more about what’s possible.

### Healthcare

IoT in the healthcare industry [helps medical professionals](https://anywhere.epam.com/business/industries/healthcare) to take better care of their patients as well as connect with them proactively in a timely manner. In fact, patients and healthcare facilities also benefit from using the possibilities of the Internet of Things in this industry.

#### Examples of IoT usage in healthcare

* [Wearable health monitoring devices](https://anywhere.epam.com/business/wearable-technology-in-healthcare)
* Sleep monitors
* Glucose monitors
* Real-time tracking of medical and monitoring equipment (like wheelchairs or defibrillators)
* Smart medication dispensers

#### Startups and their applications for healthcare industry

[Aira](https://aira.io/) — uses latest IoT technologies to connect blind people with highly-trained professionals who help them with daily activities by providing visual information

[AliveCor](https://www.kardia.com/) — offers two products ([KardiaMobile](https://store.kardia.com/products/kardiamobile) and [Kardia Mobile 6L](https://store.kardia.com/products/kardiamobile6l)) for monitoring heart condition

[AwarePoint](https://www.cbinsights.com/company/awarepoint) — provides IoT sensors to track locations of patients and medical equipment in real-time

[Kinsa](https://kinsahealth.com/) — offers various smart thermometers as a way to detect contagious illnesses early

[Medisafe](https://www.medisafeapp.com/) — creators of medication reminder app called Medisafe (available on Android and iOS)

### Logistics and transportation

IoT helps optimize logistics and transportation processes of goods and people by tracking objects and vehicles as well as by transferring current data about the transports. IoT can also be used to control elements of the transport process remotely.

#### Examples of IoT usage in logistics and transportation

* Warehouse management
* Finding alternative routes
* Predictive analytics (finding the best routes or checking the effectiveness of drivers)
* Traffic management

#### Startups and their applications for logistics and transportation industries

* [HERE Tracking](https://developer.here.com/products/tracking)– software for indoor and outdoor tracking of devices and assets that EPAM created together with HERE Technologies
* [Hopstack](https://www.hopstack.io/) — warehouse automation via IoT sensors
* [InnoTech](https://innotechco.com/index.php/logistics/) — package condition management
* [IOTech](https://www.iotechsys.com/the-smart-retail-real-time-sensor-fusion/) — solution integrating retail and logistics via sensor platform
* [Syook](https://www.syook.com/tito) — fleet tracking sensors as a solution called TiTo (Truck in Truck out)
* Tive — solution for tracking location of high-value goods

### Retail

[IoT in the retail industry](https://anywhere.epam.com/business/industries/retail) can be used to improve both customer experience and retail management — making it easier, better and faster. The Internet of Things is also a way to provide digital experiences for customers visiting physical stores.

#### Examples of IoT usage in the retail industry

* Retail management and tracking
* Optimization of product placement
* Improvement of customer experience (i.e. using IoT to detect confused or impatient customers and informing in-store staff about them)
* Inventory management

#### Startups and their applications for the retail industry

* [EVRYTHNG](https://evrythng.com/) — provides data on company-owned or manufactured products and is being used by brands like Ralph Lauren and Coca-Cola
* [CONEX](https://conexsolution.com/) — smart visual merchandising and quality images for interactive displays
* [Stockwell](https://www.stockwell.ai/) — manufacturers of vending machines, called smart stores, that can be adapted to the particular space they will be placed in. For example, fitness clubs can fill vending machines with post-workout products

### Smart home

Using the Internet of Things in homes is about controlling domestic appliances remotely and, if needed, automatically. In other words, using IoT apps and smart devices allows for almost total control over a house and its surroundings (like a garden) without the need of being there physically.

#### Examples of using IoT in the smart home industry

* Energy usage control system
* Lighting and audio control systems
* Noise, water damage, smoke and fire detectors
* Remote-controlled handles and curtains
* Garden watering system

#### Startups and their smart home applications

* SimpliSafe — provides home IoT security solutions for detecting potential intruders, water damage, and fire
* [Span.io](https://www.span.io/) — offers smart electrical panels that consumers can connect to an app, allowing them to control energy usage at home
* [SmartRent](https://smartrent.com/) — smart home products and solutions dedicated to those renting properties and homebuilders
* LinpTech — manufacturer of smart doorbells and curtains for both residential and commercial buildings

## Creating an IoT application: mobile app or web app?

If you’ve already chosen a niche for which you want to build an IoT app, it’s time to decide whether it’s better to build a mobile application or a web application.

### Why it’s better to build a mobile app vs web app

1. Better discoverability, as you can add your app to AppStore or Google Store
2. Better accessibility to the device’s features and resources (and that means greater functionality)
3. Better security, as mobile apps must be approved before being added to the app store
4. Mobile apps can work without an active Internet connection, i.e. via Bluetooth
5. They are usually faster and easier to build than web apps

### Why it’s better to build a web app vs mobile app

1. Lower development costs
2. They work straight in a browser, so it’s not necessary to download them
3. There is no need to build two separate apps, which might be the case if you want to build a mobile app
4. They are easier to maintain and update
5. They don’t have to be approved by anyone, so you can launch quickly

Not sure what to choose? Contact us to get help from the EPAM Anywhere Business team.

[tell us about your project](https://anywhere.epam.com/business/contact-us)

## What’s under the hood: Build an IoT application using these components

Every Internet of Things application requires four elements: cloud technology, dedicated hardware, a reliable network, and intuitive software.

### Cloud

One of the most important elements of IoT, responsible for data processing and storage.

### Hardware

Low-energy sensors or mobile devices that can be either custom-built or bought from third-party vendors.

### Network

Responsible for two-way communication between all relevant IoT devices, and properly linking these devices with each other.

### Software

Software is responsible for managing all devices within an IoT system. Whether you choose to develop a mobile app or a web app, the software should be cloud-based. Additionally, users should be able to check information collected from sensors and devices via one dashboard.

## The tech stack you need to create a winning IoT application

The technology stack needed to create an IoT app consists of the following: programming language, framework, cloud IoT platform, protocol, hardware and sensors. Combine them according to your specific tech requirements, and, if uncertain, don't be shy about reaching out to experts for professional solutions.

### Programming languages

* C/C++
* JavaScript
* Python
* Ruby

### Frameworks

* Node.js
* IoT.js
* Device.js
* AngularJS

### Cloud platforms

* Arduino (open source)
* AWS (Amazon Web Services) IoT
* Google Cloud IoT
* IBM Watson
* Microsoft Azure IoT
* OpenHAB

### Protocols

* 2G/3G/4G/LTE/5G
* AMQP
* MQTT
* Wi-Fi

### Hardware

* Arduino
* FPGA controllers
* Google TPU
* Raspberry PI

### Sensors

* 1-Wire
* ADC
* Analog
* RF433

Not sure which one is best for your case? Contact us to get help from the EPAM Anywhere Business team.

[contact us today](https://anywhere.epam.com/business/contact-us)

## How to make IoT applications that users rely upon

At EPAM, we advise you to build a Minimum Viable Product (or Minimum Viable Application in this case) to verify your idea as fast as possible and improve it according to feedback you receive from initial customers.

And when it comes to the development process itself – we’ve prepared a list of recommended steps to implement when building high-quality IoT products, ones that people will keep using them again and again.

### Step 1: UI/UX design

An IoT app — like any other app — needs a design that’s not only good looking but also user-friendly. Experienced designers can help ensure this aspect is taken care of properly. You can find them in a variety of ways, i.e. on Behance or by looking for app design agencies and checking their portfolios.

Before you start developing your own app, you need to know the importance of good UI/UX design – it’s what separates successful apps from those that get removed quickly. For example, disappointed people will leave bad reviews on AppStore or Google Play and that will have a bad effect on a number of downloads.

Make sure that the user flow is logical and there are no errors like buttons leading to nowhere. For the end user, using your app should feel natural and intuitive, without unnecessary guesswork.

### Step 2: Front-end development

One of the most popular programming languages for developing front-end is JavaScript (according to a [StackOverflow](https://insights.stackoverflow.com/survey/2021#technology-most-popular-technologies) Developer Survey). There are many frameworks built upon JS, like Angular, React or Vue, that boost the software development process and provide great developer experience. Choosing one usually depends on individual preferences, experience or requirements of the particular project (or a combination of these factors).

### Step 3: Back-end development

Back-end development is a bit more complicated, as you need to choose more tools that must be compatible with each other. We already covered cloud platforms before; here, you must also choose a programming language, database management system and DevOps tool.

If you decide to go with JavaScript to build a front-end layer, then the natural choice for back-end programming would be Node.js, as it’s also built upon JavaScript.

**Database** — CrateDB, InfluxDB, MongoDB, RethinkDB, SQLite Database

**DevOps tools** — Gradie, Jenkins, Docker

### Step 4: Quality assurance — automated or manual testing

Before launching, test your application to discover as many bugs as possible and fix them. Be prepared to receive bug reports from the users and to quickly fix them as well.

### Step 5: Collect users’ feedback and improve your app accordingly

After launching your app, listen to your initial users, collect their feedback and create a roadmap describing what fixes or new features will be implemented and when. Make this roadmap available to your users so they know you treat them seriously and that you intend to improve your app over time.

## How much does it cost to make an IoT app in 2022?

Before diving into average rates for developing IoT applications, it’s important to understand what factors determine the final price. This includes:

* App complexity (i.e. number of features)
* Application security level
* Number of API integrations
* Operating system
* Type of application (mobile or web)
* UI/UX design complexity (i.e. how many screens need to be coded)

## Developing applications for the Internet of Things with enterprise-level experts from EPAM Anywhere Business

Working with EPAM Anywhere Business to develop an IoT applications means:

* **Great user experience** — usability of IoT apps is something we take very seriously from day one, as there is no point of building any app that won’t be user-friendly;
* **Broad expertise** — for every project we take on, we assemble a development team of people with the most relevant skills and experience;
* **High-level app security** — we make sure that app data will be stored and well-protected at every level;
* **Scalability** — thanks to our microservice-based architecture, there is always the ability to scale IoT applications by adding new features or integrations and expanding a list of supported devices.

## Conclusion

This article is intended to acquaint you with the fundamentals of developing IoT applications. We’ve covered things like industries with high demand for IoT apps, components of the Internet of Things, the right tech stack and a step-by-step process for building apps people will use. As the demand for IoT applications keeps growing globally, more and more companies will try to jump in and secure their positions in verticals like retail or healthcare.

If you are interested in joining them, let the EPAM Anywhere Business team help you and contact us.

[estimate price](https://anywhere.epam.com/business/software-development-cost-calculator)

## FAQ

What is needed for an IoT application?

What is an app in IoT?

How do I code IoT?

[Facebook](https://www.facebook.com/sharer/sharer.php?u=https%3A%2F%2Fanywhere.epam.com%2Fbusiness%2Fhow-to-build-an-iot-application)[Twitter](https://twitter.com/share?text=&url=https%3A%2F%2Fanywhere.epam.com%2Fbusiness%2Fhow-to-build-an-iot-application)[LinkedIn](https://www.linkedin.com/shareArticle?url=https%3A%2F%2Fanywhere.epam.com%2Fbusiness%2Fhow-to-build-an-iot-application)[Send via email](mailto:?subject=How%20to%20Create%20an%20IoT%20App:%20Internet%20of%20Things%20for%20Your%20Success%20|%20EPAM%20Anywhere%20Business&body=https%253A%252F%252Fanywhere.epam.com%252Fbusiness%252Fhow-to-build-an-iot-application)Copy link

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