DZone

THE DZONE GUIDE TO

# INTERNET OF THINGS

VOLUME III

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# DEAR READER,

First there were long and short buzzes on a wire, then an imaginary tape with a read/write head and some memory, then some noise-cleaning discretization of those buzzes…then runaway fissile chain-reactions threatened and computers had to talk to one another even if a few of them died. Packet-switching was invented to connect machines that might fail over channels that might fail in case of nuclear holocaust – and these days we're complaining about battery life and getting chills because HTTP/2 lets us run multiple request/responses on a single TCP connection.

The physical implementation of information-processing systems has come a long way – driven often by the fact that hardware fails. So when we shudder at the unreliability of constrained IoT devices, we're really just rehashing the old problem that inspired Shannon entropy, RAID systems, lineage-based data reconstruction, CAP, FLP, vector clocks, eventual consistency..and thousands of years ago drove Plato to give up on defect-ridden physical existence altogether and millions of years ago steered multiple nucleotide sequences to encode a single polypeptide.

Precisely because the Internet was designed for robust, fault-tolerant information transfer, it is not exactly optimized for the modern Internet of Netflix (giant files sliced up into blocks sent at a rate just beyond the video bitrate) plus wireless sensor networks (not all of whose outputs mean anything in isolation) – an app-level global payload set structure on top of (and semantically resembling) the lower-level 'mice and elephants' picture of Internet traffic. To lighten the backbone load, large-scale Internet engineers are pushing CDN-like ideas deeper into the information topology and developing content-centric and named data networking. But application developers won't need to worry about the Internet at this level.

But developers who build applications that run on constrained devices and interact with the physical environment do have to think about these matters – about what happens to Things when you connect them to the Internet, and what happens to the Internet when you use it to connect Things. Some problems posed by IoT are unavoidable, functions of the messiness of the corporeal. But other problems can be solved entirely – and even many of the basic problems can be mitigated to acceptable levels – by software solutions that we're just beginning to develop.

To help developers navigate the vast and mostly uncharted IoT domain and technical solution spaces, we've assembled this year's DZone Guide to the Internet of Things, covering everything from the IP/network layer all the way up the constrained cyberphysical ladder. Check out our latest research and let us know what you think.

**BY JOHN ESPOSITO**

EDITOR-IN-CHIEF, DZONE RESEARCH@DZONE.COM

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to our topic experts, Zone Leaders, trusted DZone Most Valuable Bloggers, and dedicated users for all their help and feedback in making this report a great success.

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# EXECUTIVE SUMMARY

**Surely we're over the IoT hype by now. The idea is an ancient dream, the technical constraints have been around for a while..and many aren't going away any time soon. But if the promise of IoT holds less luster than it enjoyed a year or two ago, the ubiquity of IP-connected devices is more apparent than ever. Application and database architects are just getting comfortable designing for network partitioning, and most mobile devices are still powerful enough (and users still sufficiently happy to recharge frequently) that deep algorithmic optimization is still more a performance improvement than a physically required sine-qua-non. But IoT is changing all that. The formerly specialized challenges of embedded development, protocol efficiency, push and streaming, network topology design, and serious power limitations are creeping into the general application developer's problem space.**

**Our latest research indicates that developers already know this – that the hype of IoT is fading into the more productive phase of actually building things, and that the tools, standards, and techniques required by IoT are increasingly important to know. We hope the following datapoints will give you a better picture of how developers are actually building Things for the Internet (and the Internet for Things).**

## The buzzword "IoT" is becoming less exciting to developers, but actual IoT technologies are becoming more familiar

DATA In 2016, developers are double-digit less likely than in 2015 to respond that IoT is "currently relevant" or "will be relevant to [their] organization in the future." But developers' awareness of IoT-optimized technologies (MQTT, CoAP, 6LoWPAN, ZigBee, Z-Wave, Bluetooth LE) is growing quickly (in many cases doubling year over year).

INTERPRETATION Developers are seeing IoT less as hype and more as reality, whether labeled by the buzzword "IoT" or not. Of course more constrained sensor-actuator devices will be connected to the Internet in the future, and in fact technologies suited to these devices—the technical reality of IoT—are becoming more familiar to developers (see additional data below).

RECOMMENDATIONS Focus IoT development efforts on solving new domain problems with the optimal technical solution, even if the optimal technology (protocol, programming model, topology) is less familiar. Avoiding the buzzword "IoT" will circumvent distaste for hype and directing extra effort toward learning and using new technologies will help emerging technical standards mature.

## Developers are facing more cyber-physical than data-related challenges

DATA Many more developers report encountering challenges related to unpredictable physical environment (47%), device unreliability (46%), power (40%), device addressing/discovery (39%), and latency (36%), than challenges related to data volume (25%) and reliability (24%).

INTERPRETATION The old division of labor between developers (making data tractable) and analysts or data scientists (making data informative) persists, even where coupling is increasingly tight between application and device speed and reliability, on the one hand, and data availability and trustworthiness, on the other.

RECOMMENDATIONS Develop a common, semitechnical discourse around all data collection, streaming, and storage efforts throughout the IoT stack—from hardware developers to data scientists and business strategists. Satisfaction rates of target SLAs around device availability, performance, and security will fluctuate more rapidly and within a wider range for IoT than for non-IoT services, making it difficult to isolate the root cause to any layer in the IoT stack (because each layer introduces heterogeneous and significantly increased unreliability). The concept of 'bounded contexts' from Domain-Driven Design may help.

## Developers feel ready to take on the programming challenges presented by IoT

DATA Most developers (87%) are either not concerned or only somewhat concerned about the new, less-mature programming and networking paradigms required or encouraged by the Internet of Things. Far more remain concerned about security (68% very concerned, 26% somewhat concerned) and privacy (53% very concerned, 38% somewhat concerned).

IMPLICATIONS Widely shared worries about IoT (privacy, security) are common to developers and non-developers. Purely technical limitations of constrained cyber-physical devices are just another challenge that developers feel confident can be overcome.

RECOMMENDATIONS Bring security professionals into IoT development projects early and at all levels of the hardware application stack. Take the same approach to IoT constraints (low power, intermittent connectivity, device unreliability, questionable data) as to other application constraints, applying paradigms already familiar from mobile and distributed applications.

## Developers currently at larger companies are more likely to adopt a new IoT-related technology in the next six months, but many developers are also interested in building an IoT-related startup

DATA Likelihood of adopting an IoT-related technology within the next six months increases with respondents' company size; and more of these respondents work at organizations with 10,000+ employees (28%) than work at any other company size segment. But 38% of respondents are interested in building an IoT-related startup (making consumer or industrial products).

IMPLICATIONS Opportunity in IoT bifurcates by organization size: large companies are likely to adopt IoT technologies because their problem surfaces are large enough to include at least some cyber-physical devices at high probability, and startups are likely to adopt IoT technologies because they can focus their efforts on a massive new (and relatively unexplored) problem space. This bifurcation is likely to persist until IoT matures.

RECOMMENDATIONS Bring security professionals into IoT development projects early and at all levels of the hardware application stack. Take the same approach to IoT constraints (low power, intermittent connectivity, device unreliability, questionable data) as to other application constraints, applying paradigms already familiar from mobile and distributed applications.

# KEY RESEARCH FINDINGS

**DEMOGRAPHICS:**

- **797 IT Professionals responded to DZone's 2016 IoT Survey**
- **The top three industries the survey takers work in are Technology (27%), Finance (10%), and Consulting (9%)**
- **40% work as a Developer/Engineer**
- **21% work at companies with more than 500 employees, 17% work where there are more than 10,000 employees**
- **61% of survey takers work on an immediate team of 2-10 people**
- **38% of respondents work at companies whose headquarters are are in Europe, 32% in the USA**

## THERE'S AN INTEREST IN IoT, AND IT'S GROWING WITHIN COMPANIES

In last year's survey, we asked respondents if they have ever worked on an IoT project, looking for a simple yes or no answer. 69% said no. This year, we added a third option: "no, but it sounds fun." Although only 30% of respondents said they have worked on IoT projects (the same as last year,) just over 44% (the majority) expressed curiosity in learning IoT, versus 26% of respondents who just said "No." People are interested, but they just need the tools and time to further explore what IoT means for them.

When asked which business contexts they are most interested in using IoT in, 61% of respondents said for hobby development. Although this remains the top interest level in the business context realm, 46% expressed interest in working on IoT-related projects within their company – a slight increase over 2015's expressed interest. IoT's momentum (albeit slow) within companies shows that developers are curious and cautiously optimistic to not only learn and work on IoT projects, but to also work on them within their own company versus on a startup or hobbyist level.

## IoT IS STILL FOR THE FUTURE

Even though there's a larger amount of interest to work on IoT-related projects within a company, there's an overwhelming consensus that these projects aren't pertinent. Only 43% of this year's respondents (down from 58% in 2015) said that IoT is currently relevant to their organization. In July of 2014, Gartner released a hype cycle of relevant topics. As you can see, in 2014, the Internet of Things was at the peak of its inflated expectations. Fast forward two years, Gartner's prediction of a down trend (in regards to hype) proves accurate for IoT.

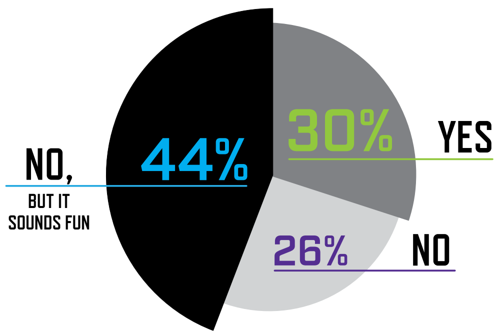
When looking to the future of IoT, 76% (down from 85% in 2015) of the respondents noted that IoT will be relevant to their organizations down the road. Although the majority still feels that IoT will be relevant for a later time, there is another down trend here compared to last year's responses. Yes, there's still an overwhelming agreement that IoT is relevant for the future, but following along with the Gartner hype cycle, this serves as further proof that IoT has already reached its peak.

## INTEREST IN TYPES OF IOT APPLICATIONS: WEARABLES DOWN, ENVIRONMENT UP

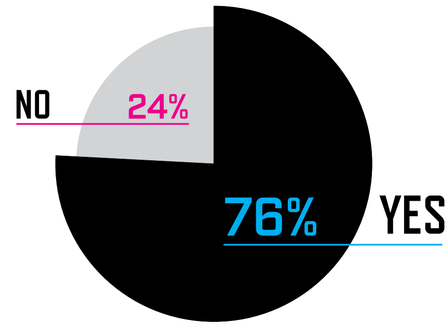
Security and privacy (68% and 53% respectively) remain the biggest concerns when it comes to IoT. The concern that centers around security and privacy could also indicate why respondents are more keen on IoT for the future within the business contexts of their companies. A lack of standards in defining IoT was a distant third in the "very concerned" column, coming in at 34%. 25% of respondents are wary of connectivity and low-power device management, 24% are worried about ubiquitous hardware and software maintenance, and 14% are apprehensive about new, less-mature programming and networking paradigms.

To piggyback on the concerns surrounding IoT, we asked the individuals in the survey pool who have experience working with developing IoT applications what challenges they have faced in the process. 47% of the respondents said that an unpredictable physical environment was the biggest challenge they faced. Following closely behind at 46% is the unreliability of the devices used. In third, at 40%, are power constraints.

01. HAVE YOU EVER WORKED ON AN IoT PROJECT?




02. WILL IoT BE RELEVANT TO YOUR ORGANIZATION IN THE FUTURE?



The top two challenges that the majority of the respondents face when building IoT applications – unpredictable physical environment and device unreliability – help spur the security and privacy concerns. The correlation between the biggest challenges and the areas for the most concern shows us that once the physical environment becomes more stable, then the concerns that surround IoT will inevitably decrease. 81% of the survey takers noted that they were not planning to adopt new IoT-related technology in the next 6 months. This not only reiterates that IoT is still for the future, but it also shows that the concerns and challenges are potentially large holdups when it comes to the implementation of IoT-related technology. If these aren't the causes of the holdups for the currency of IoT, then these challenges and concerns could be rooted in the lack of knowledge and set definitions of IoT in general.

**HOME AUTOMATION PIQUES THE INTEREST** Home automation/smart home (and home utilities) has remained the use case in which the majority of survey takers expressed interest in working on, or have already worked on. 26% of respondents have worked on IoT projects in this area, and an additional 66% expressed interest in wanting to work on a related project in the future. As for other use cases that make the top of the list, Environmental has replaced Drones/Remote Controlled vehicles as the second most prominent use case, with 11% having actually worked in this area and 65% expressing interest versus 10% and 64%.

Of the people who own smart home products – only 26% of the audience – the most prevalent product is smart utilities (i.e. water control and thermostat) at 55% of this group, followed by smart lighting at 50% and home security (i.e. door locks, cameras, motion sensors) at 49%.

**IoT TOOLS ARE STILL RELATIVELY UNKNOWN** It comes as no surprise that developers' main IoT technology of choice is Raspberry Pi, with 75% of respondents noting they own this prototyping board. In a distant second, at 46%, was Arduino. However, when it comes to overall protocol awareness, these results have shifted year over year. This year, Bluetooth LE and Wi-Fi Direct are the two most prominent protocols that the survey takers have either heard of or dabbled with. On the opposite end of the spectrum, most respondents have never heard of 6LoWPAN or CoAP, with 82% and 84% of the audience respectively. We gave the survey pool the options of the mDNS or DNS-SD protocols as tools they use for IoT service discovery, and the majority of the people have either never heard of them, or—if they were familiar with them—they had never used them. Only 12% have used mDNS and 5% DNS-SD.

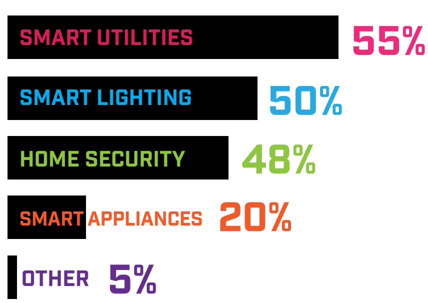
When we shifted gears and asked about familiarity and use of operating systems for IoT applications, the respondents gave similar answers as they did with the protocol questions. The majority of the survey takers (an average of just over 80%) have either never heard of or used any of the following IoT applications: TinyOS, Contiki, LiteOS, or Riot OS. The main application that some have either played with or used in production is Android (for anything other than phones, that is,) with 35% having tinkered with it, and 24% having actually used it in production. One notable write-in includes Raspbian, with 3% having played with it and 2% having actually used it in production. A second notable write-in includes Linux, with 2% having played with it and 5% noted they have used it in production.

With the overall low level of awareness and use of these IoT protocols, operating systems, and prototyping boards, we can see that there is a lot of growth potential and knowledge to be shared. After all, 55% (up slightly from 52% last year) of the the survey takers noted that they would rather build an IoT project or product from scratch versus working on an already existing project. As a helpful tool to further explain and break down these unknowns, make sure to check out the Infographic on Page 16.

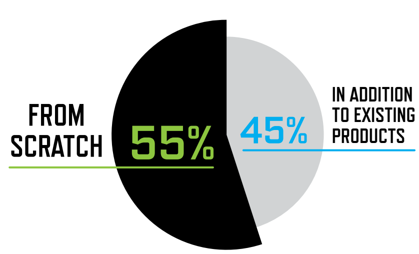
**03. HOW CONCERNED ARE YOU ABOUT THE FOLLOWING ISSUES IN THE CONTEXT OF IoT?**

| | NOT CONCERNED | SOMEWHAT CONCERNED | VERY CONCERNED |
|---|---|---|---|
| PRIVACY | 9% | 38% | 53% |
| SECURITY | 6% | 26% | 68% |
| LESS MATURE PROGRAMMING + NETWORKING PARADIGMS | 36% | 53% | 14% |
| CONNECTIVITY+ LOW-POWER DEVICE MGMT. | 27% | 49% | 25% |
| UBIQUITOUS H.W. + S.W. MAINT. | 24% | 53% | 23% |
| LACK OF STANDARDS | 19% | 47% | 34% |

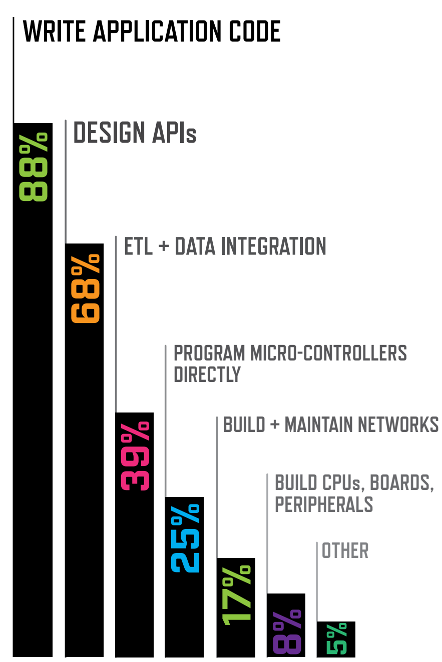
**04. WHAT TYPES OF IoT HOME PRODUCTS DO YOU OWN?**




**05. WOULD YOU BE MORE LIKELY TO BUILD IoT PRODUCTS FROM SCRATCH, OR AS ADDITIONS TO EXISTING PRODUCTS?**




**06. WHAT TASK ARE YOU LIKELY TO PERFORM WHILE DEVELOPING AN IOT PRODUCT?**



# Expanding the Frontiers of Connectivity:

## SCALING YOUR ARCHITECTURE FOR THE INTERNET OF THINGS

### QUICK VIEW

**01**
The Internet of Things (IoT) is driving an architectural shift Edge Layer that is breaking the traditional client-server model.

**02**
IoT requires a new Edge Layer, which is responsible for being the first line of connectivity for devices to connect to before they go to the back-end systems—the server.

**03**
Readers will learn about a new reference architecture for IoT and what role the Edge Layer plays in it.

**BY ROSS MASON**
FOUNDER, MULESOFT

A company's success is now directly linked to how well it connects applications, data and devices. The way organizations compete today depends upon how efficiently they can do this. But the notion of what a "device" is has changed radically. Today, the term "device" means anything connected that isn't a traditional web client. Sensors, connected machinery, street lighting, and appliances, among other things, are all now becoming connected devices. This shift to smart, connected devices is referred to as IoT, or the Internet of Things. We now wear devices, we use them for every daily activity, and they interact with our environment at home, at work and everywhere in between. They are becoming an increasingly important part of the fabric of everyday life.

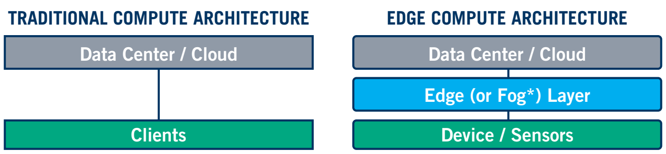
The value that the enterprise gets out of these devices isn't contained within the devices themselves. Rather, their value to the enterprise is the data they collect and the way the enterprise either reacts to that data or uses it to create new services and products.

Because the notion of connected devices is infiltrating many areas of our lives that we  do see and many more that we don't, the conversations on IoT come from different angles, different spaces, and solutions for different things. There is a large spectrum of connected items ranging from the consumer through to enterprise to industrial use.

| | CONSUMER | ENTERPRISE | INDUSTRIAL |
|---|---|---|---|
| DEVICES | Wearables, home devices, stuff you can back on Kickstarter and Indiegogo | Commercial machines like cars, medical devices, billboards, vending machines | 'Internet of Things that spin' – jet engines, oil pumps, turbines, industrial site management |
| VALUE MODEL | Value is in the device itself. The value to the consumer is in the Insights it provides (e.g. your fitness) and the experiences it enables (e.g comfortable temperatures at all times at home) | Value is in the digital services that device enables for better customer experiences such as loyalty programs or safety alerts for medical devices or for management/ maintenance such as equipment failures and auto refill order for vending machines | Value is in the instrumentation and analytics to reduce costs. In the industrial space, the cost of unscheduled downtime and manual maintenance checks runs into the hundreds of millions of dollars per year |
| VALUE MODEL BUSINESS MODEL | Subscription service model (e.g. preemptive maintenance) or consumer engagement (e.g loyalty programs) | Subscription service model (e.g. preemptive maintenance) or consumer engagement (e.g loyalty programs) | Platform solutions for running industry verticals i.e. factory management, pipeline monitoring |

## IoT REPRESENTS AN ARCHITECTURAL SHIFT

IoT is changing the computer hardware model that we've had for the past 40 plus years. Consider all the different phases of hardware models that have existed: green screen to mini-computer to PC, and today to cloud and mobile. The computer architecture has been consistent – Client and Server. What's changed over the years are the clients. For IoT, however, there's a difference. There is actually a third hardware layer which breaks the traditional client-server model. Developers and architects are used to building software systems across two physical tiers. But for non-traditional web clients, there's a new notion of a third tier. This is an emerging concept, spearheaded by research at Princeton University, and it's called the Fog Layer or the Edge Layer. It is responsible for being the first line of connectivity for these devices to connect to before they go to the back-end systems – the server.




## THE NEW EDGE LAYER

The Edge Layer is responsible for connecting devices locally, and manages the data collection and connection to the server. The benefits of this approach are:

- **Data filtration:** First pass data filtering reduces the amount data transmitted but retains the meaning of the data.
- **Connectivity protection:** Device connectivity doesn't fail if the network fails or there is an intermittent connection. The Edge Layer is responsible for handling outages and store and forward data.
- **Site level management:** Enables site level orchestration across devices from different vendors using different protocols.
- **Device agnostic control:** Site abstraction allowing server/ cloud application to be agnostic to the device implementation it controls.

The Edge Layer has three main components in a typical IoT deployment.

1. The device or sensor itself. In IoT this is the client that generates data and/or receives commands to execute.
2. Most devices will connect to a gateway that enables access to the Internet or a private network. Typically these gateways speak a proprietary protocol between the connected devices and then allow connectivity through the gateway using a standard protocol such as HTTP.
3. The Edge Controller is responsible for connecting to all the gateways and independent devices in a physical location. The Edge control collects and collates data from all the devices, transmits data, and accepts commands from the server to execute across some or all the devices.

The server layer is similar to what we already see in other client server architectures, such as mobile. Many of the boxes in the Server layer will seem familiar because most of these components may already exist in your enterprise. The key pieces are:

- The API Layer is leveraged by IoT architecture to connect to the server layer. This provides consistency, control, governance, security and an analytics-based model for connecting external sites.

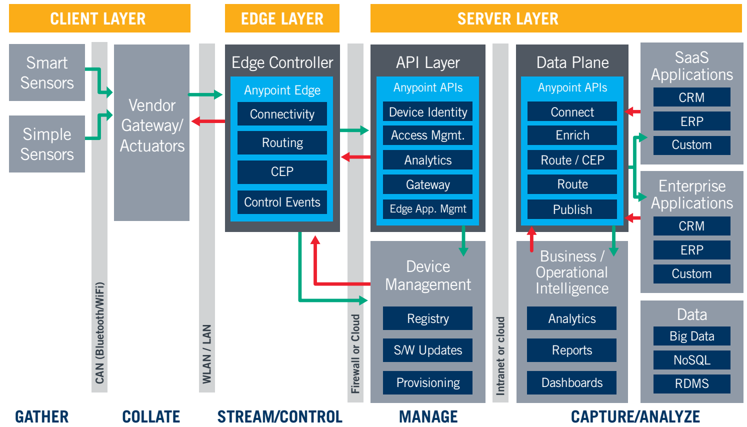



**FIGURE 1** MULESOFT'S REFERENCE ARCHITECTURE FOR IOT APPLICATIONS COVERING THE CLIENT LAYER, EDGE LAYER, AND SERVER LAYER.

- Device Management is responsible for knowing what devices are within the IoT network and sometimes is part of the authentication chain. Device management is also responsible for upgrading software on the Edge controller and possibly the gateways too.
- The Data Plane provides the event streaming, transformation orchestration and connectivity to the applications and systems that at can use the data coming from the Edge layer.
- SaaS applications, Enterprise applications, Big Data and BI are typically the consumers of the data coming from the Edge Layer; they make it actionable through analytics, dashboards, and application processing.

## CONCLUSION

At its heart, IoT is about capturing and leveraging data being generated by connected devices; they create the physical Web, blurring the lines between how we interact between the physical and digital. The future for IoT seems promising with many IoT networks already connecting elements of the physical world. In the architecture I just described, the Edge Layer of the network will be responsible for performing collation of data and real-time event processing to allow automated tasks. This IoT architecture reduces the amount of data sent to back-end systems and provides a control interface that can access and manage local devices and sensors. The role of APIs at this Edge Layer is critical to providing easy access to connected devices, either through a hub or directly.

*This is an abridged extract from Ross Mason's new book 'First, Break IT', available for free download.*

**ROSS MASON** is founder of MuleSoft. Ross founded MuleSoft in 2006 on the idea that connecting applications should be easy, building on the open source Mule project he created three years earlier. He is responsible for MuleSoft's product strategy, open source leadership, engineering alignment and direct engagement with customers.

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# Code the Industrial Internet with Predix

The Industrial Internet of Things (IIoT) provides brand new ways to innovate entire industries, enabling higher operational efficiencies and net outcomes for customers. For example, trains can now self-optimize their route plans, wind turbines can perform self-maintenance checks, and aircraft engines can self-optimize for better fuel efficiency.

To derive the benefits of the Industrial Internet, it is critical for industrial companies to rapidly transform into software companies, and to adopt some best practices for application development and delivery.

However, tools and techniques built for consumer IoT usually doesn't work well in the industrial world. The industry technical requirements are different. There are physical devices to manage, many of them with lifespans of 30 years or more. Regulatory compliance, security, and health & safety concerns are top of the list challenges. Data volumes grow twice as fast as in the consumer Web. There is also a need to integrate with an array of industrial control systems, like SCADA, PCL, etc.

Meet Predix by GE. The power of Predix is its industrial-strength strength, created for industry by the company that knows industry. It is built to deliver the benefits of DevOps, Cloud, and Microservices, all while delivering on industrial demands. High-performing IT organizations experience 60X fewer failures and recover from failure 168X faster than their lower-performing peers. They also deploy 30X more frequently with 200X shorter lead times.[1]

Predix is built on Cloud Foundry, and we worked to harden and ready Cloud Foundry for the Industrial Internet. The Predix Machine device gateway connects assets to the Predix Cloud. Predix provides industry-strength security, through industrial firewall technology, and by applying encryption, authentication, and threat detection. And since Predix provides a catalog with ready-made services, it can be thought of as an app store for industrial services.

With Predix, software developers now have a powerful platform to code, build, deploy, and operate industrial apps, using modern design and development principles. GE developed Predix to work with languages such as Java, JavaScript, C++, PHP, Python, Ruby, and MATLAB.

I'd like to invite you try Predix for yourself, at www.predix.io.

[1] Puppet (www.puppet.com), 2015 State DevOps Report

**WRITTEN BY LOTHAR SCHUBERT**
DIRECTOR, PREDIX DEVELOPER RELATIONS, **GE DIGITAL**

PARTNER SPOTLIGHT

## Predix BY GE DIGITAL

GE Digital

**Predix is the cloud platform for the Industrial Internet. Built on Cloud Foundry, Predix is optimized for secure connectivity and analytics at scale.**

**CATEGORY**
Industrial Internet

**OPEN SOURCE?**
Yes/No

**CASE STUDY**

From space, Norfolk Southern's 20,000-mile rail system resembles a neural network. And it increasingly works like one, thanks to GE's Movement Planner, an Industrial Internet app that helps guide hundreds of trains traveling the railroad's network across 22 states daily. Powered by GE Predix, Movement Planner uses big data to improve machine and infrastructure efficiency and help the environment. The app takes logistical information and combines it with schedules, track grades, train movement, and other data. As a result, trains run faster and more efficiently on existing routes without laying new tracks. Since the company turned on Movement Planner a few years ago, fuel use is down 6.3%, and velocity is up 10% to 20%.

**STRENGTHS**

- Edge device connectivity
- Analytics for "Digital Twin"
- Asset management framework
- Industrial-strength Cloud
- DevOps for Industrial Apps

**NOTABLE CUSTOMERS**

- Pitney Bowes
- RasGas
- E.ON
- Exelon
- City of San Diego
- Toshiba
- Lixil

**BLOG** predix.io/blog | **TWITTER** @Predix | **WEBSITE** www.predix.io

# The Industrial Internet and Its Overlap with Nature

QUICK VIEW

**01**
Taking cues from Nature, a new networking paradigm is presented, supporting billions of devices.

**02**
Building the gasket to support "chirp:" cheap and copious devices that are too dumb to run IP.

**03**
How to ensure devices and their controllers keep working – with no "Cloud" in sight.

**BY FRANCIS DACOSTA**
FOUNDER AND CTO, MESHDYNAMICS

## PART 1
## NETWORK ARCHITECTURE

The architecture of the emerging IoT will necessarily entail both a different architecture and a different communications protocol. My book Rethinking the Internet of Things: A Scalable Approach to Connecting Everything (Apress, 2013), explains why.

I believe that the exponential explosion of the Internet of Things will be driven by entirely new phenomena:

- Device populations will be in the millions and possibly trillions (if we believe the hype over why IPV6 is needed).
- The total cost of ownership for many of these sensors, devices, and actuators must be exceedingly low in terms of device purchase cost, power consumption, and (especially) management overhead.
- The vast majority of IoT communications will be machine-to-machine, with *no human directly involved.*

These differences mandate rethinking how we build IOT systems. Referring to Figure 1, I suggest a three-tiered, tree-like logical network architecture. The approach draws upon lessons from nature, such as the propagation of pollen and the interaction of social insects, and allows massive scale with the minimum overhead in each device.

Simple IoT devices, the leaves of the "tree," are serviced by intermediate branch network elements. These **propagators** manage message routing and protocol translation services. Another class of devices, at the tree trunk, perform the (big data) **integrator** functions. They provide higher-level analysis with human interaction, both for near-edge analytics and broader-scope analysis and control.

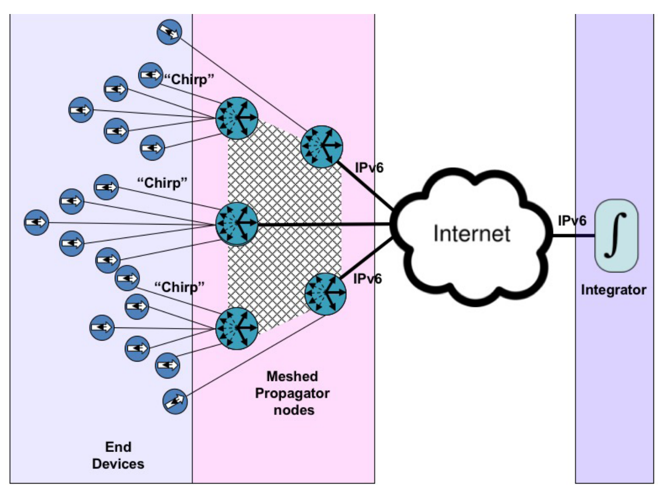



FIGURE 1: DEVICES, PROPAGATORS, AND INTEGRATORS

### PURPOSE BUILT PROTOCOLS

As the vast majority of IoT communications will be machine-to-machine (M2M), with *no human directly involved*, there is good reason to rethink the Internet of Things. It's less about the "Internet" and more about the "Things" and their interchange. This demands simpler, lighter, purpose-built protocols. I call these "chirps" because birds' chirps are terse, repetitive, and redundant by design.

Referring to Figure 2, chirps are efficient, extensible data frames with a structure that includes an open-source device type ID, public and private data fields, and a simple checksum. The chirp is inherently structured for the kinds of machine-to-machine communication that will become the norm in the Internet of Things. Think of it as a variant of UDP designed for machines.

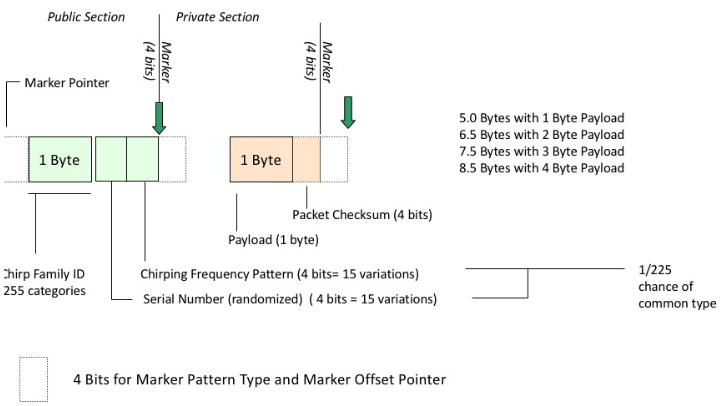



**FIGURE 2**: EXEMPLARY OPEN CHIRP PROTOCOL

It's what a chirp *does* ***not*** have that makes it perfect for the emerging IoT! There is no guarantee of delivery, no unique device identifier, and no higher-level routing information. Just like "dumb" birds chirping, any individual squib of M2M traffic is *non-critical*, so chirp devices don't bother with *any* of this overhead.

Staying "dumb" vastly reduces the processing and electrical power, management overhead, and total ownership cost of the end device. The chirp is thus extremely efficient with bandwidth and processing power en route, requiring only five bytes total for a one-byte payload compared to forty bytes for an IPv6 packet.

## SCALABLE M2M MESSAGING

While efficiency is nice, the true power of chirp protocols lies in how they're used in real time publish/subscribe data streams. This is where big data searches for, discovers, and meets "small" data.

Unlike traditional peer-to-peer or client-server architectures, the open-source options of chirps allow data integrators to incorporate sensor data streams from a variety of public and private sources into their analysis of a location or situation. Based on the open-source Device Type ID and extensions, data integrators may discover interesting data streams based on geography, data patterns, or other characteristics driven by big data subscription interests. These may be combined with other traditional information sources (for example, weather or news feeds) to create meaningful information, alarms, reports, and other actions. Thus, "small" data eventually swims upstream to integrators where the "big" data fishes feed.

Propagator nodes are like traditional networking devices such as routers and access points, and incorporate many of their functions. But, they have important additional capabilities to meet the need of translating chirp data flows into small data streams that in turn may be passed to the big-data integrator functions.

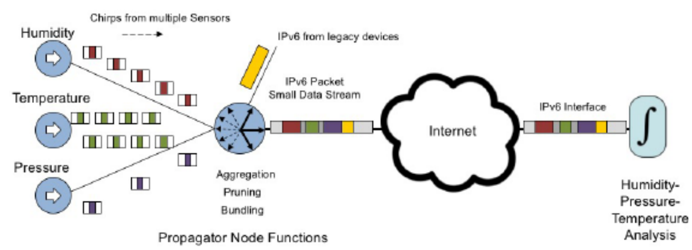



**FIGURE 3**: PROPAGATORS BUNDLE AND PRUNE CHIRP STREAMS

As shown in Figure 1, propagator nodes discover and network with like devices to create a structured (mesh) network. This structured network permits individual propagators to intelligently bundle, prune, aggregate, and spoof data as needed to maximize efficiency, see Figure 3. In this way, they function much like traditional networking gear.

But, there is an important difference which may be likened to the difference between a mailroom and a highly skilled executive assistant. A mail room simply shuffles packages based on addresses—whether the boss wants it or not, she will receive anything addressed to her. Traditional routers are like that mailroom.

The propagator node is like an experienced and knowledgeable executive assistant. Knowing his boss' preferences and interests, he will send her only the most important mail and packages, discarding junk mail and handling lower-level correspondence on his own. Propagators may likewise be biased and programmed by instructions from the integrator while also spoofing or discarding unimportant data streams.

It is entirely conceivable, in the near future, to see a "flock" of propagator drones "dust" a corn field (or battleground) with miniature chirp sensors—the much talked-about sensor "dust." Such chirp-based pollen will be inexpensive enough to be able to emulate Nature's tested schemes, like pollination at spring. This is relentless flooding for an extended period of time: a big no-no in the IP world.

It works, every year, on a massive scale—with billions of devices. It scales because only specific flowers/subscribers know how to decode and act on the pollen "message" based on its genetic ID.

Rethinking the Internet of Things must focus on the "Things" and less on "Internet" connectivity. As IoT devices at the edge and their networks evolve, they will "naturally" move towards semi-autonomous ecosystems with their own machine Esperanto—chirp speak.

### PEACEFUL COEXISTENCE

Will all IoT devices use chirp protocols? Of course not; more sophisticated (and power-hungry) devices like set-top boxes or surveillance systems will continue to be IPv6. These are incorporated into the emerging IoT topology along with chirp data (from simpler sensors) in the propagator nodes. Propagators provide the bridging from IP to chirp and back, on an as-needed basis.

## PART 2
## THE INDUSTRIAL INTERNET: FOCUS IN THE ENTERPRISE

As the new buzzword "Industrial Internet" implies, the massive future scaling of the Internet of Things will be driven by *enterprises.* To name just a few: natural resource extraction, process-oriented manufacturers, factory floor, military, transportation, municipality, and security applications will each require hundreds of thousands or millions of IoT end points. The accompanying scale and networking complexities will drive a need for the IoT architecture introduced in part one of this article "Architectural Necessities of the Internet of Things" (and described more completely in my book, *Rethinking the Internet of Things: A Scalable Approach to Connecting Everything*; Apress, 2013).

For enterprises to fully exploit the potential of the Internet of Things, a transition and integration path must be defined so that legacy devices and networks may incorporate data based on the coming IoT architecture. At the same time, demanding enterprise applications require a high degree of robustness in terms of mobility, routing around failures, and future-proofing, which is *by design* not provided in the IoT chirp protocol (to minimize end device total cost of ownership).

The propagator node, as described in my previous article, is critical to bringing vast amounts of simple chirp IoT data onto the network (enterprise, cloud, and/or Internet). Propagator nodes incorporate traditional networking functionality along with:

- Translation and management of IoT chirp data streams into IP data packets
- Self-organization and maintenance of a structured network despite disruption and mobility (Disruption Tolerant Networks)
- Optional inclusion of applications agents to interact with big-data integrators
- Optional local client services through applications agent (e.g. to your smart phone)

Propagators thus manage IoT chirp data streams and also integrate existing IP data sources. These include legacy IP traffic as well as chirps embedded in IP packets with device-type IDs upon which the propagator may act (as can be seen in Figure 4)

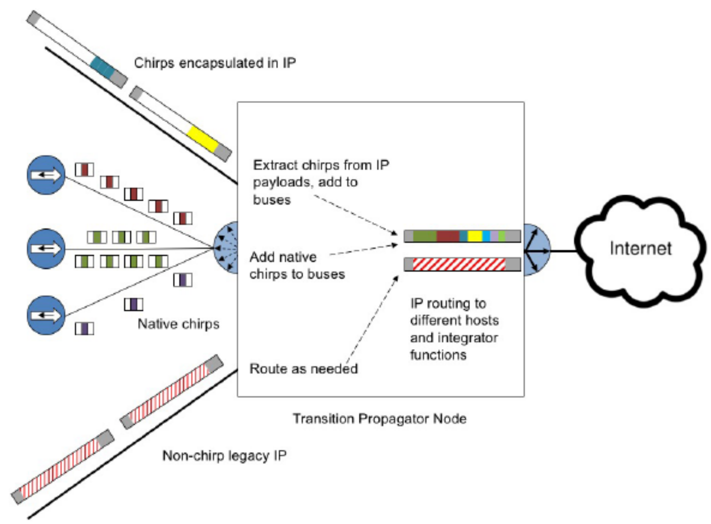



FIGURE 4: PROPAGATOR NODE IN TRANSITION ENTERPRISE NETWORK

Because propagators bundle, prune, and shuttle chirps, a thorough understanding of the network topology between and among propagators will be necessary—and, this must be acted on autonomously by the propagator nodes themselves.

This is accomplished by structuring a logical tree from a physically meshed wireless network. Propagator nodes locate adjacent nodes, negotiate active links based on control system algorithms, and place less-desirable paths into standby mode. These alternate paths may be activated nearly instantaneously based on disruptions such as degradation of signal, interference, loss of a node, etc. (See a list of related patents here.)

Security is always a concern with IP-based "things" and their Internet connectivity. But IP is Greek to chirp devices. Protocol translation occurs at propagators, with a full audit trail of what came in on the IP "channel" and went out on the chirp "channel." Propagators are the new secure intermediaries between chirp networks and their parents' Internet. Economies of scale favor putting high end IP encryption at these more power hungry gateways, versus putting it on simpler and low power IoT devices.

## APPLICATION AGENTS

As outlined earlier in this article, the emerging IoT architecture recognizes the coming explosion of very simple devices communicating via efficient chirps. Because this terse messaging protocol lacks the overhead for end-to-end, peer-to-peer networking by design, this challenge is addressed by applications agents optionally deployed in some or all of the propagator nodes in an enterprise (see Figure 5).

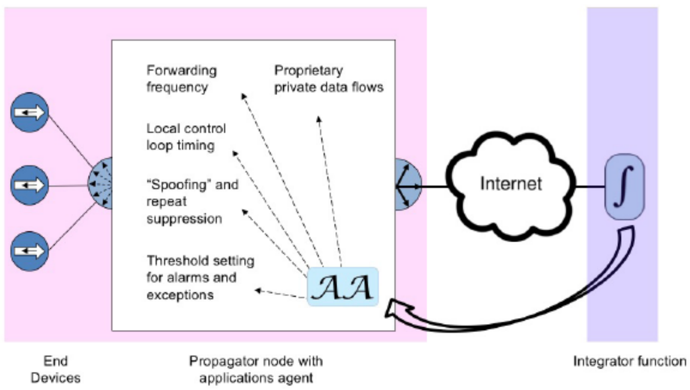



**FIGURE 5:** APPLICATIONS AGENT IN PROPAGATOR NODE

Applications agents move intelligence to the edge of the network to manage traffic, provide local client services, and permit some degree of independent real-time response to changing conditions in the IoT. Higher-level functions (such as the integrator) may bias the propagator the parameters for what data is forwarded, what is discarded, and what is spoofed to local chirp devices. Thresholds may be set for creation of alarms and boundary conditions. In addition, private and proprietary traffic may be encrypted as needed based on using the private marker within the chirp.

## LOCAL AUTONOMY

Applications agents also deliver a degree of autonomy to the propagator node and its local devices. Local processes may continue uninterrupted through the disruption of a network connection, decrease the amount of traffic in the enterprise network, and enable a degree of localized machine learning based on past events and conditions. Only exceptions and parameter-setting traffic need be exchanged between remote locations and the centralized big-data integrators, with much of the day-to-day operation handled by the applications agents. Control loops need no "round-trip" from a local device across the enterprise or Internet backbone to the integrator function and back. Instead, the local and backbone control loops become isochronous, maximizing local responsiveness (Figure 6).

## DISCOVERY

This autonomy may be extended to the discovery of unknown chirp data streams. Because chirps are identified

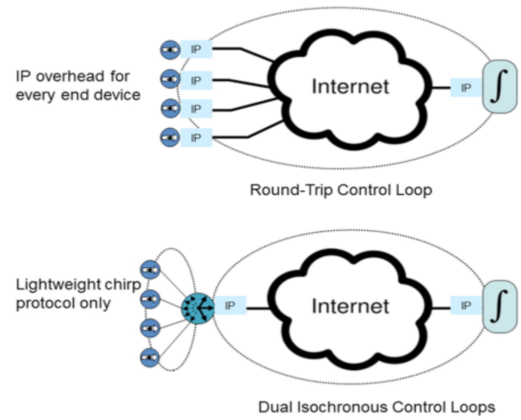



**FIGURE 6:** DECOUPLING CONTROL LOOPS TO MINIMIZE OVERHEAD AND INCREASE RESPONSIVENESS

by device type, the applications agent in a local propagator node may find interesting data flows based on device type (moisture sensor, strain gauge, etc.), time-of-day, or signal pattern (correspondence with known data streams). These potentially useful data flows may be presented by the applications agents to integrator functions as potential subscriptions.

Propagator nodes are already finding use cases in a variety of enterprises. An international OEM is deploying transition propagator nodes to provide local Wi-Fi hotspots, connect digital signage, and connect environmental sensors. Likewise, some military applications are deploying chirp devices and propagator nodes to provide the secure network bridging between them and their parents' Internet.

"New military Internet of Things applications demand huge numbers of extremely simple end devices. Based on size and power, chirp is the only viable networking protocol, and thus a robust disruption tolerant propagator is necessary to connect these effectively. Combining simple devices with existing IPv6 equipment via the propagator is also an important demand of many missions," said Curtis White, Sr. Research Systems Engineer, Space and Navy Warfare Center, Atlantic.

Enterprises will be a fundamental driver of the scaling of the Internet of Things—and, propagator nodes engender the transition of legacy networks to an emerging, more appropriate IoT architecture, servicing billions of simpler, cheaper, and often mobile edge devices.

Author **FRANCIS DACOSTA** is the founder and CTO at MeshDynamics. He previously founded Advanced Cybernetics Group, providing robot control system software for mission-critical applications, including both local and supervisory real-time M2M control. At MITRE, he served as an advisor to the United States Air Force Robotics and Automation Center of Excellence (RACE). Francis also held senior technical positions at Northrop Grumman, Ingersoll-Rand, Xerox. He has an MS from Stanford University and BS from Indian Institute of Technology.

# Architecting for Dynamic Analytics in IoT

**BY DENIS CANTY**
LEAD TECHNOLOGIST DATA SCIENCE AND IoT STRATEGY, **TYCO'S INNOVATION GARAGE**

## QUICK VIEW

**01**
Architecting solutions in IoT is a complex game, with partitions between cloud, edge gateway and devices causing many challenges for developers.

**02**
Analytics will play a crucial role in IoT, and analytics applications should be designed to be dynamic and to function across distributed compute topologies using cascading design paradigms.

**03**
Analytics applications developers should understand the difference between "insight from data" and "impact from data" for their customers.

The expected flood of data from billions of connected devices is raising many challenges for how IoT solutions will be architected. Common design paradigms from device-to-cloud will allow more flexibility on how compute will best be utilised for data analytics. A big challenge is where do we place data analytics: on device, at the edge, or in the cloud?

Just what role does data analytics play in the Internet of Things? Whilst there is no single definition of IoT, it is good to define IoT from a Data Analytics (DA) perspective – "Applying algorithms to data from smart devices that leads to process (industrial IoT) and life (consumer IoT) optimisation." IoT is the train that data analytics was waiting all these years for. Billions of devices producing data. A marriage made in heaven.

## WHERE THE CHALLENGES LIE

Two frequent problem statements from developers working on data analytics use cases in IoT are 1: "I can't place any analytics on the device or gateway as it just doesn't have the resources to cope with the amount of data," and 2: "How do we store and process all the data?"

Looking at 1, if developers could look to classify the data into two buckets at edge and device, namely 1: use now data and 2: use later data, then it can begin to perform local data reduction by pre analytics. This will ensure we can minimise data storage and transfer rates, and free up compute for device based analytics.

Looking at 2, the first step for any data scientist after getting a data set is to cleanse it. This by its very existence should suggest that we don't need all the data to make the decision required for business impact, as there is still a lot of junk data being generated by these IoT devices.

## INTRODUCING HAZE COMPUTING

IoT edge gateways are now an essential part of IoT applications. But where does the edge begin and end? Compute exists right from the devices all the way to cloud, so why should the gateway be treated any differently? In fact, in lots of cases the pooled compute of the devices that are connected to the gateway can exceed what is available at the edge gateway. The challenge is how devices are configured in Machine to Machine (M2M). It is predicted here that the classic gateway will be squeezed from above by cloud and below from devices, and it may become distributed by design.

What is being proposed here is to create a dynamic model for your analytics applications, which I name presently as Haze Computing (named due to coverage from device to cloud), where you begin with a pooled view of your resources. Each DA app that you build analyses the local and global compute available to it across cloud, edge and device(s), and the haze data management controllers (DMC) aggregate and design how and where analytics take place in a dynamic fashion.

By being a little more clever at the data source, one can both reduce the amount of data being kept locally and pushed to cloud by designing a data consistency aware messaging service from cloud to device that serves a series of DMC that are in sync and take control over other messaging communication for IoT. Each IoT application for a single device would have its own cloud DMC, device DMC and edge DMC. Their purpose is to manage the data's 3V's (velocity, volume, variety) and the application of analytics

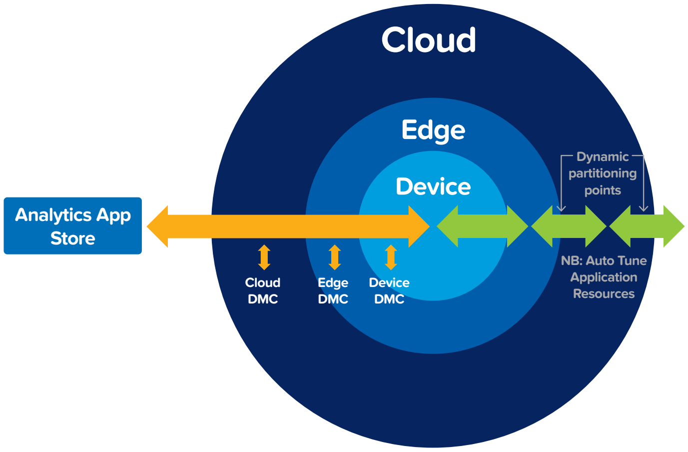



FIGURE 1: HAZE COMPUTING

apps on the data stream at predefined intervals. Having this type of architecture will ensure you can scale your applications and services across cloud, edge and device.

This holistic design approach for IoT shown at a high level in figure 1, has many advantages including:

### SECURITY

The single view per IoT application ensures that security can be better managed across device, edge and cloud. Security and privacy are still the main concerns for IoT practitioners across the industry. Applying a more holistic architecture design makes implementing next generation security topologies much easier. One such topology is blockchain, of bit coin fame. If you consider that the cloud application can act as the parent blockchain that can spawn multiple sidechains at the edge, which can in turn manage device based sidechains, then you can create a security ecosystem that is automatic, based on consensus, and fully auditable.

### ENERGY EFFICIENCY

If developers can become more conscious and implement green computing paradigms at the haze level, where energy usage rates are much more visible, then best practices can be designed and built much easier. Normally the more data we have to process, store, and transfer means the more energy that will be consumed. This architecture ensures you can reduce the energy use as each DMC acts as a data filter point.

### REDUCE COMPLEXITY

It is common for developers to be slightly behind in where the trends are within the IoT landscape. One main reason for this is normally we have experts in one of the areas required to build full breadth IoT applications, and there are a myriad of technologies with various design practices that are not in sync. This architecture will allow developers to eliminate design chasms across edge, device and cloud, and introduce simplicity in IoT standards being driven by the IIC and OPC.

## CASCADING ANALYTICS MODEL FOR IOT

Having this type of dynamic haze architecture outlined above will allow for a cascading model for analytics. Everyone will have seen the impact apps have on our technology fingerprint as individuals. Analytics use cases are just apps. And like any app, there can be an app store to host it in. And those apps can be installed all the way from personal computers to tablets, phones and wearable's. It's still the same app at its core. A retail store assistant in a city may only require data from that city, however a regional manager may require the same application with data from the entire state.

With container based technologies such as Docker now becoming more mainstream, it is becoming easier to move or expand your applications across your IoT application domain and function exactly the same. These technologies will ensure that you can build your apps once, and deploy to many device types.

- Analytics will need to be dynamic for IoT, architecture allows analytics to move across IoT compute spectrum
- Decision making acts like a neural network for IoT analytics

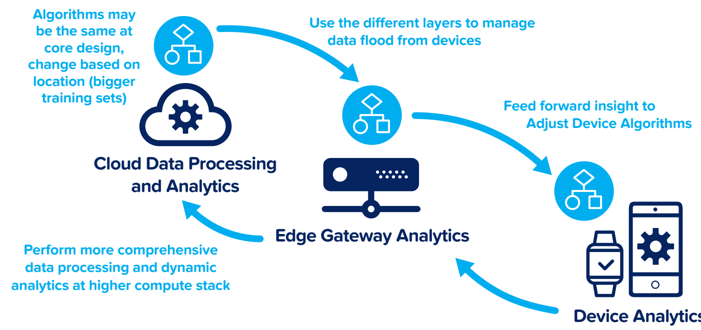



FIGURE 2: CASCADING ANALYTICS

Whilst IoT can be a huge source of both data and challenges that can be solved with the data, it can be easy for developers to get distracted. Regardless of consumer or industrial IoT, an idea might be to start small with a simple classifier at the device level. Build on this at the edge, with some more advanced time-based analysis. Then once you get to cloud level, use the vast compute and applications you have there to run much more sophisticated machine learning algorithms on your data. However, ensure that this learning is fed back to your simplistic model at the device and edge, so that you can improve your data models over time. Thus applying iterative reinforcement learning down through your cascaded analytics model.

Finally, the single most important aspect to building any analytics application in IoT is to ensure you keep the customer at the centre of the discussions right from the start, a form of agile IoT. Too often the fragmented nature of how business is done means that a huge amount of insight is discovered, but if there isn't a dollar value attached to it, then it will stay exactly that. The key aspect is to ensure you can translate the "insight" to "impact". This is where your customers will see the key role analytics plays in their IoT strategic future.

**DENIS CANTY** is the Lead Technologist for Data Science and IoT Strategy with Tyco's Innovation Garage, focused at sensing and building analytics applications to solve customer challenges. He holds a Masters in Computer Science and a Masters in Microelectronic IC Design. Denis is passionate about promoting STEM careers for future generations. Denis is on twitter @deniscanty, and his blog is at deniscanty.wordpress.com.

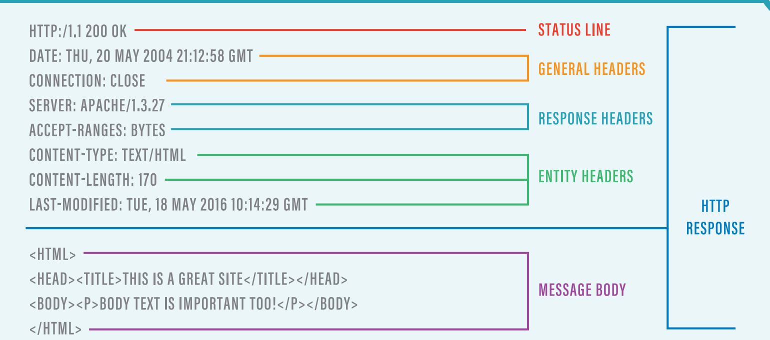
# THINNING
## THE INTERNET FOR THINGS

The TCP/IP stack, designed to maintain communications in case of nuclear war, is built on the interaction model of the telephone – reliable multiplexed conversation between agents that ask for clarification, slowdown, and rerouting when needed. But many IoT devices and applications, along with their supporting networks, are too constrained, too real-time, or simply too busy to worry quite as much about end-to-end reliability.

The Internet needs to get thinner to accommodate weaker devices and bigger data. Here's a comparison between familiar Internet protocols and some new, lighter-weight analogues optimized for IoT.

# WEB

## HTTP: THE HYPERTEXT TRANSFER PROTOCOL

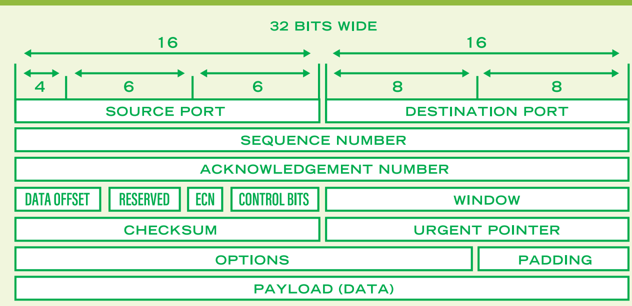



- Synchronous request/response over TCP
- Human-readable (HTTP/1.1) or binary (HTTP/2)
- Supports only reliable (OK) transport
- Depends on TCP-level transport reliability
- Supports unicast over TCP/IP (1machine-1machine) or simulated multicast in app layer (expensive)

## TLS: TRANSPORT LAYER SECURITY

- Depends on TCP-level guarantees -> send vs. receive diff implies attack
- Assumes TCP handshake -> sender IP address must be real

## TCP: TRANSMISSION CONTROL PROTOCOL




- Header overhead: 20 bytes
- Three-way handshake (SYN-ACK-ACK) to establish connection -> delay before data transfer begins
- Opens bidirectional tunnel -> send & receive byte order match guaranteed
- Aware of connection state -> keeps packets ordered, resends on fail
- Send rate throttling -> responds to congestion

## IPV4/V6: INTERNET PROTOCOL V4/V6

- Maximum transit unit (MTU): 1280 octets
- Normal packet size: 1.5-9kb
- Max frame header: 40 octets
- Required source/destination addresses
- Designed for reliability and recoverability

# IoT

## CoAP: THE CONSTRAINED APPLICATION PROTOCOL

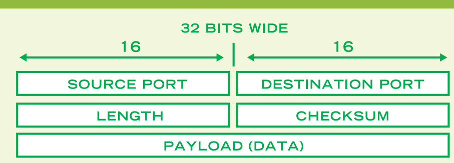
| 1 BYTE | | | 1 BYTE | 2 BYTE | TKL BYTES | VARIABLE | 1 BYTE | VARIABLE |
|---|---|---|---|---|---|---|---|---|
| VERSION | TYPE | TKL | CODE | MESSAGE ID | TOKEN (IF ANY) | OPTIONS (IF ANY) | 0xFF (IF PAYLOAD) | PAYLOAD (IF ANY) |

- Asynchronous request/response over UDP
- Binary
- Maps 1:1 onto HTTP
- Supports both reliable (ACK reqd) and unreliable (ACK not reqd) transport
- Messages designed to occupy payload section of UDP datagram
- Needs DTLS for security (to fill UDP gaps vs. TCP)
- Supports IP multicast (1machine-many machines) via UDP

## DTLS: DATAGRAM TRANSPORT LAYER SECURITY

- Re-implements retransmission, ordering, other 'tunneling' functions handled by TCP and not by UDP
- Does not assume TCP-level guarantees -> sequence number explicit in record, anomalous records (authentication code mismatch, duplicates, significantly outside window scope) dropped -> send vs. receive diff noise indistinguishable from attack
- Does not assume handshake -> sender IP address can be spoofed in UDP datagram -> optional transmit-back sender verification
- Offers TCP-level guarantee overhead when needed on top of UDP

## UDP: USER DATAGRAM PROTOCOL




- Header overhead: 8 bytes
- No handshake to establish connection -> minimal delay before data transfer begins
- No byte order specified -> if order is important, must be reconstructed at higher levels
- Ignorant of connection state -> less robust against failure, no resend on fail
- No send rate throttling -> doesn't respond to congestion (results in loss)
- Lightweight = less power, less bandwidth
- Streaming: smart device data loss more acceptable, latency less acceptable

## 6LOWPAN: IPV6 OVER LOW-POWER PERSONAL AREA NETWORKS (IEEE 802.15.4)

- Max packet size: 127 octets
- Max frame header: 25 octets
- Optional source/destination addresses
- Neighbor discovery optimized for constrained devices, mesh topologies, unreliable networks

# For Wearables in the Enterprise, the Future is Now

**BY AMY GRODEN-MORRISON**
VICE PRESIDENT OF MARKETING, **ALPHA SOFTWARE CORPORATION**

## QUICK VIEW

**01**
The wearables market is taking off, with analysts predicting 215 million units selling annually by 2019.

**02**
Sixty-eight percent of global technology and business decision-makers say wearables are a priority for their company.

**03**
Head mounted displays will grow out of their niche and become mainstream enterprise devices.

**04**
Vendors offering wearable development tools include Alpha Software, APX Labs, Good Technology and Salesforce.

Depending on whom you ask, wearable devices such as smartwatches will either be relegated to consumer playthings or end up playing a vital role in business and IT strategies at companies of all sizes. This piece takes a deep dive into what analysts and research studies say about the role wearables will play in business in the coming years — and look at how developers can take advantage of existing tools to explore wearable applications today.

## WHAT ANALYSTS SAY ABOUT THE GROWTH OF WEARABLES

Analysts universally agree that the wearable market is poised for takeoff. Gartner forecasts that worldwide wearable device sales will generate total revenue of $28.7 billion (274.6 million units) in 2016, up 18.4% over 2015 (232 million units). A big chunk of that will come from smartwatches — $11.5 billion this year – and leading the way will be the Apple Watch. Angela McIntyre, research director at Gartner, explains, "From 2015 through 2017, smartwatch adoption will have 48 percent growth largely due to Apple popularizing wearables as a lifestyle trend. Smartwatches have the greatest revenue potential among all wearables through 2019, reaching $17.5 billion." [1]

The same report also cites that head mounted displays (HMDs), which are currently little more than a market afterthought, are on track to become mainstream devices, and will grow from 140,000 units sold in 2015 to 6.31 million in 2017. Forecasters also predict that these devices will have significant uses in businesses. The report notes, "Enterprise use of HMDs will also grow in the coming years with 26 percent of HMDs designed for business use in 2018. HMDs will be purchased by businesses for use by employees for tasks such as equipment repair, inspections and maintenance. Workers also will use HMDs for viewing instructions and directions hands-free while they are performing a task."

IDC offers similar forecasts about the wearables market. Its Worldwide Quarterly Wearable Device Tracker says the world wearable device market "will reach a total of 111.1 million units shipped in 2016, up a strong 44.4% from the 80 million units expected to ship shipped in 2015."[2] IDC predicts that by 2019, total wearables sales will reach 214.6 million units for a five-year compound annual growth rate (CAGR) of 28%.

## WEARABLES IN THE ENTERPRISE

Smartwatches and fitness trackers are the most visible wearables aimed at consumers. But wearables are expected to become big in the enterprise as well, according to reports and analysts, and will result in billions of dollars of benefits for the companies who use them. Why? One way to think about wearables is that they can be viewed as sensors, and businesses have increasingly been incorporating sensors into their IT business applications and mobile apps in recent years. For example, a smartwatch is a sensor connected to the body – it has a sensor that monitors your heart rate, temperature or movement and that information can be collected and transmitted to a mobile device. This is not different conceptually from industrial sensors – for example, a temperature sensor that resides in a refrigerated delivery truck or a motion sensor that monitors room usage. In the context of mobile devices and applications, the concept of a sensor and a wearable are going to be interchangeable. Both collect data, and mobile apps are all about reacting, displaying and responding to data.

Given this similarity, businesses are already signaling a sizable demand for wearable technology. Forrester Research's "The Enterprise Wearables Journey" found that: "Today, 51 percent of technology and business leaders identify wearables as a critical, high, or moderate priority for their organization."[3]

APX Labs, which offers solutions for smart glasses and smartwatches, predicts in its report, "What's Next in Wearable Technology," that "enterprise adoption of wearables will jump by six-fold in 2016. Enterprise deployments will rapidly grow from the dozens to the thousands as wearables reach a greater level of maturity and market acceptance."[4] It also says that 2016 "will bring the slow motion collision of the Internet of Things and wearables." The report adds, "Wearable devices, such as smart glasses, represent an unprecedented opportunity to interact with real-time sensor information, workflows and reference documents, as well as collaborate with other workers in a hands-free manner." The company claims that 93% of companies it surveyed are using or actively evaluating wearables.

Compass Intelligence estimates that business and enterprise use of wearables will have a 139% CAGR from 2014 to 2019, with growth driven by the medical/healthcare, industrial, oil & gas, and field services industries.

Gartner is particularly bullish on smart glasses bringing innovation to the workplace and improving efficiency. Technicians, engineers and other workers in field service, maintenance, healthcare and manufacturing will be the initial beneficiaries. Angela McIntyre at Gartner, says, "In the next three to five years, the industry that is likely to experience the greatest benefit from smart glasses is field service, potentially increasing profits by $1 billion annually. The greatest savings in field service will come from diagnosing and fixing problems more quickly and without needing to bring additional experts to remote sites." [5]

Forrester Research analyst J.P. Gownder is also a big believer in the future of wearables in the enterprise. He notes that, "While consumers' interest in wearables has grown strong, businesses' demand for wearables is even greater. Today, 68% of global technology and business decision-makers say that wearables are a priority for their firm, with 51% calling it a moderate, high, or critical priority. [6]

## DEVELOPMENT AND DEPLOYMENT TOOLS FOR EXPLORING WEARABLES TODAY

Given the adoption of mobile devices and wearables in enterprises, what is considered a business productivity app will change. While spreadsheets and other traditional business applications won't go away, developers will need to hone their skills to develop critical task-based apps or alerts that work well on smaller screens or incorporate mobile data like voice, photos or video.

Clearly, wearables are poised to become big in the enterprise this year — and there's plenty that developers can do today to be prepared. The following table summarizes the offerings of four vendors that provide tools to help developers begin to integrate wearable technology into enterprises.

| VENDOR | WEARABLE DEVELOPMENT TOOL | URL |
|---|---|---|
| ALPHA SOFTWARE | Alpha WatchBench, free tool lets users create a working prototype app for Apple Watch using their iPhone. | alphasoftware.com/watchbench |
| GOOD TECHNOLOGY | Enterprise mobility management platform supports Apple Watch. | us.blackberry.com/enterprise/products/good-secure-emm-suites.html |
| SALESFORCE | Salesforce Wear, a set of tools, open source code, and workflow for more than a dozen wearable devices. | developer.salesforce.com/wear |
| APX LABS | Solutions for integrating smart glasses and smart watches into the enterprise. | apx-labs.com |

The upshot of all this? Wearables will become increasingly important in enterprises, beginning in 2016 and developers should be prepared for the resulting app requests. By applying their previous experience with sensors and mobile apps, and utilizing some of the new wearable prototyping and development tools available, they can begin to explore the possibilities and test early ideas for wearable apps. At that point, they'll be ready to lead their organization into the IoT age.

[1] Gartner Says Worldwide Wearable Devices Sales to Grow 18.4 Percent in 2016, Gartner, February 2016.

[2] IDC Forecasts Worldwide Shipments of Wearables to Surpass 200 Million in 2019, Driven by Strong Smartwatch Growth, IDC, December 2015.

[3] Forrester Research Report: The Enterprise Wearables Journey, Forrester Research, March 2015, Page 2.

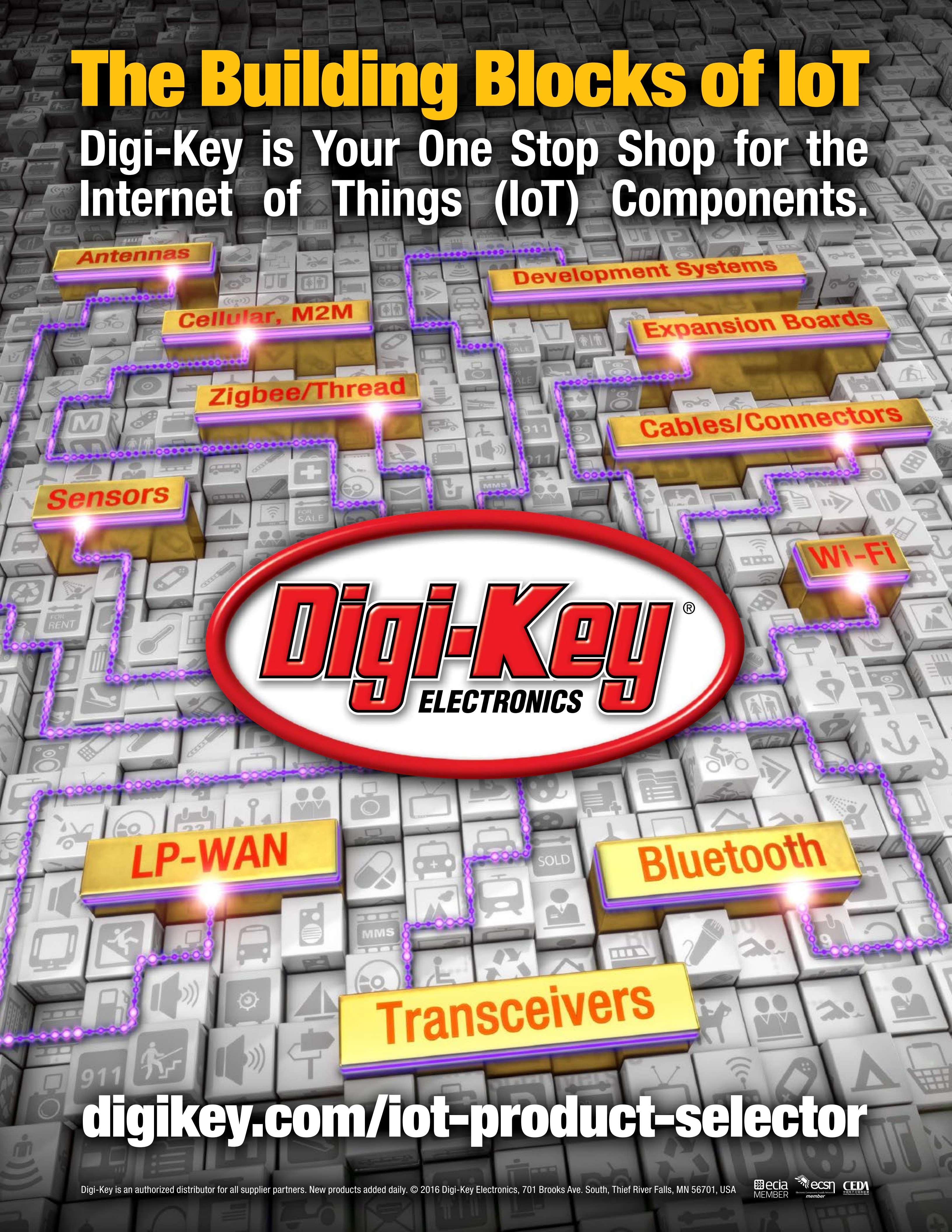
[4] Predictions for 2016: What's Next in Wearable Technology, APX Labs, 2015, Pages 3, 5.

[5] Gartner Says Smartglasses Will Bring Innovation to Workplace Efficiency, Gartner, November 2013.

[6] Five Key Truths About Wearables That Every Leader Should Know, Gownder, J.P., Forrester Research, December 2015.

As Vice President of Marketing, **AMY GRODEN-MORRISON** is responsible for product positioning, go-to-market and communications programs for Alpha Software Corporation. She has served over 15 years in marketing communications leadership roles at companies such as TIBCO Software, Spotfire, RSA Security and Ziff-Davis.

Follow her on Twitter at @agmorriso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Digi-Key is Your One Stop Shop for the Internet of Things (IoT) Components.
Antennas
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Cellular, M2M
Expansion Boards
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# From Maker to Market: Wireless Hardware Certification for IoT Scalability

Hardware platforms such as BeagleBone, Raspberry Pi, Arduino and others offer fast and simple solutions for developing a connected product. Many thousands have utilized this method to deploy quickly; these platforms are often our choice for working on last minute demos for events and tradeshows. Here are a few things to review before you decide to utilize some of these platform boards within your design.

### FCC CERTIFICATION

Selling a finished electronic device requires, at a minimum, unintentional radiator testing and most of these boards have been through this test as well as many expansion boards for use with these systems. When using a wireless device (Bluetooth, Wi-Fi, etc.), it's important to select a board that utilizes a pre-certified module to avoid the cost and time to test for compliance later. Changing the antenna on a transmitter can significantly increase or decrease the strength of the signal from that transmitter, so the FCC Part 15 standards take the antenna specifications into account. While it may be best to use the same antenna the unit was tested with, it is required to use an antenna that is electrically identical with the original antenna.

### CELLULAR CERTIFICATION

When utilizing cellular networks it's best to ensure that the device is Carrier-approved as an end-device. The carrier can at any time 'boot' non-approved devices off of their networks. This will be an expensive issue to remedy and can be detrimental to getting a product to market. Avoid these issues by using a cellular module that is end-device certified; this will be clear in the documentation as to what certs apply.

### BLUETOOTH QUALIFICATION

The Bluetooth SIG requires product that uses Bluetooth Technology to go through its qualification process. The easy path is to utilize a module that already has a QD ID (Qualified Design ID) which can be looked up by part number or manufacturer on Bluetooth.org. Other Alliance-based protocols will have their own certification requirements.

Certification requirements update all the time so it is best to stay up-to-date with the current requirements to ensure your device won't hit the certification wall deep into your design.

WRITTEN BY JOSH MICKOLIO

PRODUCT MANAGER, DIGI-KEY ELECTRONICS

# IoT Executive Insights

**BY MATT WERNER**

SENIOR EDITOR, **DZONE**

## QUICK VIEW

**01**
Security is by far the most important issue facing the widespread adoption and advancement of IoT technology.

**02**
As sensors become more advanced, low-power technology will be necessary to keep them operating for longer, and advanced big data analytics will be necessary to make the most use of the data they collect.

**03**
Those trying to develop IoT products will need an equal amount of experience both developing software and engineering hardware.

In order to learn more about the state of the Internet of Things and where it will grow from here, we interviewed 32 executives across a variety of industries actively involved in using or developing IoT solutions.

**Paul Hansen**, CEO, bbotx, Inc. • **Anders Wallgren**, CTO, Electric Cloud • **Scott Hilton**, Executive VP Products, Dyn • **Darren Guccione**, CEO, Keeper Security • **Johan den Haan**, CTO, Mendix • **Suraj Kumar**, General Manager, Axway • **Brad Bush**, COO, and **Jeanette Cajide**, VP of Corporate Development, Dialexa • **Mathieu Bassaic**, VP Product Management, Flexera • **Tony Paine**, CEO, Kepware • **Mikko Jarva**, CTO, Comptel • **Tom Hunt**, CEO, Windspring • **Craig McNeil**, Managing Director of IoT, Accenture • **Joan Wrabetz**, CTO, Quali • **Aaron Lint**, VP of Research, Arxan • **Rod McLane and Justin Ruiz**, Marketing, Ayla Networks • **Kevin Bromber**, CEO, MyDevices • **Ziv Lautman**, Co-Founder, BreezoMeter • **Gibson Tang**, Consultant, Azukisoft • **John McDonald**, CEO, CloudOne • **Ezhilarasan Natarajan**, VP and Global Head, Cloud Services, Beyondsoft • **Chris Locher**, VP Software Development, The Nerdery • **Lancen LaChance**, VP Product Management, GlobalSign • **Ryan Betts**, CTO, VoltDB • **Nav Dhunay**, CEO, ambyint • **Steve Wilkes**, CTO, Striim • **Casey Markee**, Founder, Mediawyse • **Mike Mason**, Head of Technology, Thoughtworks • **Leon Hounshell**, CTO, and **Jim Hunter**, Chief Scientist and Technology Evangelist, Greenwave Systems • **Cyril Brignone**, CEO, Arrayent

There was no majority decision on just one definition of the Internet of Things, but all the answers suggested that IoT is, at the very least, a network of connected devices. From there, two additional caveats were popular among the respondents. The first was that these devices have to be able to either sense, measure, react to, detect, or transmit data between each other and a software platform. The second was that these devices must be able to operate without continuous human interaction, since the Internet of Things is supposed to make data collection as painless as possible.

From the perspective of these executives, healthcare and home automation are two areas where IoT is currently doing the most good right now. Both personal fitness wearables (e.g. FitBit, Jawbone) and patient monitoring devices in hospitals can help everyday users and medical professionals keep track of vital health statistics. On the home automation front, tools like Nest can help homeowners save money on utilities, and new products like Amazon Echo can ensure their homes are secure while they're on vacation or out on errands. There are several use cases that fall into the category of "industrial IoT" that focus on making manufacturing and energy consumption more efficient.

Several technologies are most commonly considered to be responsible for the rise in IoT technology: low-power devices and messaging protocols, sensor networks, and analytics solutions. Many of the connected devices that make up the Internet of Things take advantage of built-in sensors to collect data. This data helps users or other devices make informed decisions and monitor outside events. Low-power technologies and messaging services are key to keeping those sensors working for longer periods of time without manual maintenance or the loss of data that can be collected. Because these sensors are able to collect more data for longer periods of time, analytics tools are becoming essential to an effective IoT system to put the most important information to good use.

While big data analytics are important to the success of IoT thus far, nearly half of the respondents also saw the space as an important area for growth, as improved analytics will only help users make the most of their IoT devices. Real-time analytics in particular will allow users to make snap decisions based on real-time data, making IoT technology even more useful and efficient. Many experts also saw an opportunity for growth in the current fragmentation of IoT standards and protocols. Many argued that if there was a way to officially standardize the way IoT devices operate and communicate with each other, it could be a huge boon to the space as a whole.

The only majority consensus between all the respondents was in regard to the barriers and pain points in developing and adopting IoT devices. Security was far and above the most pressing issue in the minds of executives, pointing both to the security of collected data, as seen in the VTech hacking debacle in December 2015, and the possibility of hacking sensors, other devices, and software. Building on the standardization issue, several executives felt that the current fragmentation may lead to adoption issues as consumers may struggle to connect devices from different manufacturers together. Another point of view worth considering, shared by a small group, believed the strategies of some companies to try and become a centralized provider of all possible IoT solutions may only be increasing fragmentation in the market. Ironically, many of these companies or non-profit consortiums may only be trying to fix the perceived standardization issue in the first place.

Wearables are currently seen as the most widely-used IoT technology right now. The second most popular option among executives was Bluetooth, a radio-based data communication standard which is currently implemented in most mobile devices and personal computers, as well as several car models. Home automation technologies were also mentioned frequently. A small group of respondents pointed out that mobile phones, which are typically used to interact with home automation systems and wearables, are owned by a vast majority of the population and could be considered IoT devices.

There was incredible diversity in the technologies that the respondents were personally interested in, as there was no overwhelming majority favorite. While home automation, medical technologies, and smart appliances attracted the most interest, many industrial IoT use cases were also exciting to numerous respondents such as agriculture monitoring, manufacturing, utilities monitoring, and smart city technology.

When asked about the best skills for developing IoT applications, an equal number of respondents believed that either hardware development, software development, or a combination of both were necessary. After that, experience with networking is preferred, as all IoT devices, as determined earlier, must be connected to the Internet at the very least. Mobile development, embedded programming, data analytics, and security experience were all tied for the third most important skill. As previously mentioned, security and analytics are key to the growth of IoT, and mobile devices are often used to interact with these devices.

To continue to drive adoption of IoT technologies, most executives agreed that new analytics tools and security protocols would be necessary to create actionable insights and ensure the safety of their customers in the process. As IoT is reliant on devices and sensors to collect accurate data, improved sensor accuracy and power consumption is also of great importance. As standardization is a major issue to many respondents, API development should also be considered to connect multiple devices together. The study of human-computer interaction and user experience, which aims to optimize the ways in which humans use technology, is another way to ensure consumers do not shy away from new, potentially groundbreaking technologies, and to further increase the adoption of future IoT ecosystems.

The executives we spoke with are fully invested in growing the Internet of Things and helping humans solve a multitude of problems in their lives and businesses. We're interested in hearing from other executives, as well as IT professionals, to see if these insights have offered any real value. Are their experiences and perspectives consistent with yours?

We welcome any and all feedback at research@dzone.com.

**MATT WERNER** is a Senior Editor at DZone, who loves learning about new technology, business culture, and organizational behavior management. He's responsible for sections of DZone's research guides and editing content in several zones. In his free time, he can be found playing with his black lab or making the walls rumble with a bass guitar.

A STEP-BY-STEP GUIDE TO

# Building an IoT Device

Building an IoT device will cost a fortune and take forever if developed the way in which traditional embedded systems have been for decades. Let's explore the steps developers should be taking when building their own IoT device.

STEP 1

## Select an IoT Platform

Starting from scratch is time-consuming, costly, and error prone! Instead, investigate and leverage existing platforms to get off the ground running.

- ☐ Identify the features that are required for the IoT device and research possible IoT platforms that contain those ready-made features.
- ☐ Consider using a platform that has operating heritage such as the Electric Imp or Renesas Synergy™ Platforms.

STEP 2

## Integrate an RTOS

Every device needs a way to accurately track time and schedule tasks. Bare metal solutions could be used, but, for an IoT device, starting with an RTOS makes the most sense.

- ☐ Identify the RTOS requirements such as preemption, stack monitoring, and tickless mode.
- ☐ Consider using an open-source or commercially available RTOS with a proven track record, such as FreeRTOS or ThreadX.

STEP 3

## Select the Programming Language of Choice

The C programming language has been used in embedded systems for over 40 years! That doesn't mean it's the right choice for every application.

- ☐ Determine whether the system has hard, real-time requirements and if so, using C might be the best choice of language with the finest low level control.
- ☐ Explore using alternative languages such as MicroPython, a Python port for microcontrollers, or the use of Java.

STEP 4

## Secure the Embedded System

One of the greatest challenges facing IoT device developers is how to secure their embedded systems. How can you secure your device?

- ☐ Lock the flash system to prevent the application from being modified.
- ☐ Use encryption to communicate with the embedded systems.
- ☐ Add an authentication layer so the system can validate who it is talking to.

STEP 5

## Optimize for Low Power

Sensor nodes are going to be one of the most common IoT devices, many of which will be battery operated. What are some simple tricks to minimize energy usage?

- ☐ Maximize the use of microcontroller sleep time.
- ☐ Set the RTOS to operate in tickless mode to keep the embedded system in sleep mode longer.
- ☐ Use automated peripherals that can transfer data and perform operations without the use of the CPU.
- ☐ Profile the embedded system for energy usage and monitor how changes to the code affect energy usage of the system.

STEP 6

## Develop a Firmware Update Strategy

Updating embedded software over the internet will be the number one way of adding new features and security updates to a device. What can be done to improve the firmware update process?

- ☐ Start developing a bootloader early in the design cycle in order to ensure that updates are as robust as possible.
- ☐ Encrypt and CRC check update packets in order to ensure that they are not corrupt.
- ☐ Use a backup image that can be restored in the event that the update fails and the system needs to recover itself.

**JACOB BENINGO** is an embedded software consultant who currently works with clients in more than a dozen countries to dramatically transform their businesses by improving product quality, cost and time to market. He has published more than 200 articles on embedded software development techniques, is a sought-after speaker and technical trainer and holds three degrees which include a Masters of Engineering from the University of Michigan. Feel free to contact him at jacob@beningo.com, at his website www.beningo.com, and sign-up for his monthly *Embedded Bytes Newsletter* here.

# SOLUTIONS DIRECTORY

This directory of platforms, middleware, software development kits, and hardware solutions provides comprehensive, factual comparisons of data gathered from third-party sources and the tool creators' organizations. Solutions are selected for inclusion in the directory based on several impartial criteria, including solution maturity, technical innovativeness, relevance, and data availability.

| PRODUCT NAME | PRODUCT TYPE | VERTICAL | WEBSITE |
|---|---|---|---|
| **Aeris** | IoT Platform, Connectivity Middleware | Healthcare, Transportation, Utilities | aeris.com |
| **Afero** | IoT Platform, Connectivity Middleware | Industrial IoT, Wearables, Medical, Transportation, Home Automation | afero.io |
| **Amazon Echo** | Consumer Product | Home Automation | amazon.com/echo |
| **Android Wear** | Developer Program, API | Wearables | android.com/wear |
| **App Cloud Lightning by Salesforce** | IoT Platform | App Development | salesforce.com/iot-cloud |
| **Apple HomeKit** | Developer Program, SDK | Home Automation | developer.apple.com/homekit |
| **Arduino Uno** | Development board | Prototyping, Hobbyists, DIY | arduino.cc |
| **ARM mbed IoT Device Platform** | IoT Platform | Device Management | mbed.com |
| **Arrayent Connect** | IoT Platform | Device Management, App Development | arrayent.com |
| **Artik 5 by Samsung** | Development board | Prototyping, Hobbyists, DIY | artik.io/modules/overview/artik-5/ |
| **Atmel Corporation** | Microcontrollers | Hardware | atmel.com |
| **Aurora by Blue Pillar** | IoT Platform | Industrial IoT | bluepillar.com/aurora-energy-network-of-things-platform |
| **AWS IoT** | IoT Platform, Connectivity Middleware | Smart City, Transportation, Healthcare | aws.amazon.com |
| **Axeda Machine Cloud by PTC** | IoT Platform, Device Management | Retail, Industrial IoT, Logistics, Utilities, Healthcare | ptc.com/axeda |
| **AXON Platform by Greenwave Systems** | Messaging Middleware | Connectivity | greenwavesystems.com/axon |
| **Ayla IoT Platform** | IoT Platform | Industrial IoT | aylanetworks.com |
| **Ayyeka Wavelets** | Sensors | Utilities, Smart City, Industrial IoT | ayyeka.com |
| **BeagleBone Black** | Development board | Prototyping, Hobbyists, DIY | beagleboard.org |
| **Belkin WeMo SDK** | Developer Program, SDK | Home Automation | developers.belkin.com/wemo/sdk |
| **BestMile** | Smart Cars | Transportation | bestmile.com |

| PRODUCT NAME | PRODUCT TYPE | VERTICAL | WEBSITE |
|---|---|---|---|
| **Bluemix by IBM** | IoT Platform | App Development, Big Data Analytics | ibm.com/bluemix |
| **Bluetooth** | IoT Devices | Wearables | bluetooth.com |
| **Blynk** | IoT Platform | Prototyping, Hobbyists, DIY, Mobile | blynk.cc |
| **Bosch IoT Suite** | IoT Platform, Device Management | Industrial IoT, Agriculture, Home Automation, Transportation, Logistics | bosch-si.com |
| **Calliope Meter** | Sensors | Home Automation, Utilities | calliopewater.com |
| **Carmine Telematics** | Fleet Management and Monitoring | Logistics | carmine.io/telematics |
| **Carriots** | IoT Platform | Device Management, Analytics | carriots.com |
| **Carvi** | Smart Cars | Transportation | getcarvi.com |
| **Casa Jasmina** | Sensors | Home Automation | casajasmina.arduino.cc/ |
| **Cisco DevNet** | Networking | Industrial IoT, Smart City | developer.cisco.com/site/iot/ |
| **CloudOne IoT Platform** | IoT Platform | Transportation, Industrial IoT, Defense, Heathcare, Home Automation, Logistics, | oncloudone.com/iot-tools |
| **Concirrus Platform** | IoT Platform | App and Device Management | concirrus.com |
| **Concrete Sensors** | Sensors | Industrial IoT | concretesensors.com |
| **Connect One** | Networking | Device Management, Healthcare, Industrial IoT, Smart City, Home Automation | connectone.com |
| **Control4 DriverWorks SDK** | Developer Program, SDK | Home Automation | control4.com |
| **CoreRFID** | Sensors | Logistics, Monitoring | corerfid.com |
| **Cumulocity** | IoT Platform | Device Management, Analytics | cumulocity.com |
| **Daintree Networks ControlScope Wireless** | Sensors, Device Management | Utilities, Home Automation, Logistics | daintree.net |
| **Datonis by Altizon** | Connectivity Middleware, Big Data Analytics | Smart City, Industrial IoT, Utilities | altizon.com/datonis-platform |
| **DeviceHive by DataArt** | IoT Platform | Connectivity, Analytics | devicehive.com |
| **Devicify** | IoT Platform | Device Management | devicify.com |
| **DGLogik** | IoT Platform | Agriculture, Analytics, Healthcare, Industrial IoT, Smart City, Logistics | dglogik.com |
| **Digi** | Networking, Sensors | Smart City, Industrial IoT | digi.com |
| **Digi-Key** | IoT Electronics | Wearables, Hardware | digikey.com |
| **Dragonboard 410c by Arrow** | Development board | Prototyping, Hobbyists, DIY | arrow.com |
| **Dweet.io by Bug Labs** | IoT Messaging Platform | Device Management, Monitoring | dweet.io |
| **Eclipse Kura** | Connectivity Middleware | Device Management | eclipse.org/kura |
| **Eclipse Vorto** | IoT Platform | Device Management | eclipse.org/vorto |

| PRODUCT NAME | PRODUCT TYPE | VERTICAL | WEBSITE |
|---|---|---|---|
| **Edison by Intel** | Development board | Prototyping, Hobbyists, DIY | intel.com/content/www/us/en/do-it-yourself/edison.html |
| **Edyn Garden Sensor** | Sensors | Agriculture | edyn.com |
| **EKOOR Green IoT** | Sensors, Beacons | Utilities, Home Automation | ekoor.io |
| **Electric Imp** | IoT Platform, Connectivity Middleware, Security | Utilities, Industrial IoT | electricimp.com/docs/ |
| **enModus** | Sensors, Connectivity Middleware | Utilities, Smart City, Home Automation | enmodus.com |
| **Etherium Computer by Slock.it** | Device Hub | Device Management, Home Automation | slock.it/ethereum_computer.html |
| **Everyware Device Cloud by Eurotech** | IoT Platform | Device Management | eurotech.com/en/products/software+services/everyware+device+cloud |
| **Evothings Studio** | Mobile App Development Platform | Device Management | evothings.com |
| **Exosite** | IoT Platform | Industrial IoT, Home Automation, Healthcare | exosite.com |
| **F5** | Networking | Industrial IoT, Smart City | f5.com |
| **Filament** | Networking | Connectivity | filament.com |
| **Fitbit** | Developer Program, API | Wearables | dev.fitbit.com |
| **Freeboard** | IoT Analytics | Device Management, Monitoring, Analytics | freeboard.io |
| **GE Predix** | IoT Platform | Device Management, Analytics | ge.com/digital/predix |
| **Gimbal Platform** | IoT Platform | Beacons, Analytics | gimbal.com |
| **Gizmo 2** | Development board | Prototyping, Hobbyists, DIY | gizmosphere.org |
| **Golgi** | Connectivity Middleware | Device Management | golgi.io |
| **Helium Smart Sensors** | Sensors | Home Automation, Environmental, Analytics | helium.com |
| **HomeStar** | IoT Platform, Messaging Middleware | Home Automation | homestar.io/about |
| **Huawei** | Networking | Industrial IoT, Smart City, Agriculture, Environmental | huawei.com |
| **Hum by Verizon** | IoT Platform | Transportation | hum.com |
| **Insteon Hub** | Developer Program, API | Home Automation | insteon.com |
| **Jasper Control Center by Cisco** | IoT Platform | Device Management, Analytics | jasper.com |
| **Jawbone UP** | Developer Program, API | Wearables | jawbone.com/up/developer |
| **Jibo** | Consumer Product | Home Automation | jibo.com |
| **Kentix360 Cloud** | IoT Platform | Device Management | kentix.com |
| **Kii** | IoT Platform | Connectivity, Device Management | en.kii.com |
| **Kinoma Create** | Development board | Prototyping, Hobbyists, DIY | kinoma.com |

| PRODUCT NAME | PRODUCT TYPE | VERTICAL | WEBSITE |
|---|---|---|---|
| **Kontakt.io** | Beacons, IoT Platform | Networking, Smart City, Industrial IoT, Home Automation, Agriculture | kontakt.io |
| **Lagoon** | Sensors | Home Automation, Industrial IoT | golagoon.com |
| **leakSMART Platform** | Sensors | Home Automation, Industrial IoT | getleaksmart.com |
| **LittleBits** | Development boards | Prototyping, Hobbyists, DIY | littlebits.cc |
| **Loop by Litmus Automation** | IoT Platform | Device Management | litmusautomation.com |
| **LoRa One by Sodaq** | Development board | Prototyping, Hobbyists, DIY | sodaq.com |
| **Losant** | IoT Platform | App Development, Device Management | losant.com/iot-platform |
| **macchina.io** | IoT Platform | App Development, Device Management | macchina.io |
| **Mender** | IoT Platform | DevOps, Automated Deployment | mender.io |
| **Meshdynamics** | Surveillance, Hardware, Networking | Security, Monitoring, Industrial IoT, Smart Grid | meshdynamics.com |
| **Meshify** | IoT Platform | Device Management, Industrial IoT | meshify.com |
| **Microduino mCookie** | Development board modules | Prototyping, Hobbyists, DIY | microduino.cc |
| **Microsoft Azure IoT Suite** | IoT Platform | Device Management, Analytics, Industrial IoT | azure.microsoft.com |
| **Mojio** | IoT Platform | Transportation | moj.io |
| **Mojo V3** | Development board | Prototyping, Hobbyists, DIY | embeddedmicro.com |
| **MuleSoft Anypoint Platform** | Connectivity Middleware | Device Management, Connectivity | mulesoft.com |
| **Muzzley** | IoT Platform | Device Management, Home Automation | muzzley.com |
| **MyDevices** | IoT Platform | App Development, Device Management | mydevices.com |
| **NATS** | Messaging Middleware | Connectivity | nats.io |
| **Nest Developer Program** | Developer Program, API | Home Automation | developer.nest.com |
| **NetBeast** | IoT Platform | App Development, Home Automation | netbeast.co |
| **Netduino 3 WiFi** | Development board | Prototyping, Hobbyists, DIY | netduino.com |
| **Netvibes Dashboard of Things** | IoT Platform | Device Management, Analytics | netvibes.com |
| **Niagra Framework by Tridium** | IoT Platform | Analytics | tridium.com |
| **Node-RED** | IoT Platform | Connectivity, Device Management | nodered.org |
| **NXP** | Processors | Hardware | nxp.com |
| **Onion Omega** | Development board | Prototyping, Hobbyists, DIY | onion.io |
| **Open Hybrid** | IoT Platform | App Development, Prototyping | openhybrid.org |
| **Oracle Internet of Things Cloud Service** | IoT Platform | Device Management, Analytics | oracle.com/solutions/internet-of-things/index.html |

| PRODUCT NAME | PRODUCT TYPE | VERTICAL | WEBSITE |
|---|---|---|---|
| **Papilio Duo by Gadget Factory** | Development board | Prototyping, Hobbyists, DIY | papilio.cc |
| **Particle Electron** | Networking | Device Management | particle.io |
| **Particle Photon** | Development board | Prototyping, Hobbyists, DIY | particle.io |
| **Pebble** | Development Program, SDK | Wearables | developer.getpebble.com |
| **Philips Hue** | Development Program, SDK | Home Automation | developers.meethue.com |
| **PlatformIO** | IDE, IoT Platform | App Development | platformio.org |
| **Pocketlab** | Sensors | Environmental | thepocketlab.com |
| **Project Jacquard** | Connected Clothing | Device Management | google.com/atap/project-jacquard/ |
| **ProSyst mBS** | Connectivity Middleware | Transportation, Healthcare, Home Automation, Utilities, Industrial IoT | prosyst.com |
| **PubNub Data Stream Network** | Networking | Connectivity, Device Management | pubnub.com |
| **Push Technology** | Networking, IoT Platform | Connectivity, Integration Platform | pushtechnology.com/solutions/iot |
| **Raspberry Pi 2 Model B** | Development board | Prototyping, Hobbyists, DIY | raspberrypi.org |
| **Razer Nabu** | Developer Program, SDK | Wearables | razerzone.com/nabu |
| **Reality Editor** | Connectivity Middleware | Messaging Device Management | realityeditor.org |
| **Red Hat JBoss A-MQ** | Connectivity Middleware | Messaging Device Management | redhat.com/en/technologies/jboss-middleware/amq |
| **Reekoh** | IoT Platform, Connectivity Middleware | Device Management | reekoh.com |
| **Remforce Boiler and Leak Monitoring** | Sensors | Home Automation | remforce.com |
| **RE-mote by Zolertia** | Development board | Prototyping, Hobbyists, DIY | zolertia.io |
| **resin.io** | IoT Platform | DevOps, Automated Deployment | resin.io |
| **RIOT OS** | Operating System | App Development | riot-os.org |
| **RTI Connext DDS Professional** | Connectivity Middleware | Messaging, Device Management | rti.com |
| **SAM Wireless Blocks** | Sensors | Prototyping, Hobbyists, DIY | samlabs.com |
| **Samsara** | Sensors | Logistics, Utilities, Industrial IoT, Environmental | samsara.com |
| **Scanalytics Floor Sensors** | Sensors | Analytics, Industrial IoT | scanalyticsinc.com |
| **Sense Home Energy Monitor** | Sensors | Home Automation, Utilities | sense.com |
| **Sierra Wireless** | Embedded Modules | Hardware | sierrawireless.com |
| **Sigfox** | Networking | Industrial IoT | sigfox.com |
| **Starfish by Silver Spring Networks** | Networking | Industrial IoT, Smart City | silverspringnet.com |

| PRODUCT NAME | PRODUCT TYPE | VERTICAL | WEBSITE |
|---|---|---|---|
| **Symphony Link Development Kit** | Development board | Prototyping, Hobbyists, DIY | link-labs.com |
| **Telit** | IoT Modules, IoT Connectivity, IoT Platforms | Smart Transportation, Agriculture, Retail, Healthcare, Automotive, Oil&Gas, Smart Manufacturing, Smart Energy, Smart Buildings | telit.com |
| **Tessel 2** | Development board | Prototyping, Hobbyists, DIY | tessel.io |
| **thethings.io** | IoT Platform | Agriculture, Logistics, Industry, Smart Home, Cities | thethings.io |
| **ThingPlus** | IoT Platform, Connectivity Middleware | App Development, Device Management, Home Automation, Agriculture | thingplus.net |
| **Thingworx Foundation by PTC** | IoT Platform | App Development, Device Management, Big Data Analytics | thingworx.com |
| **TI Connected Launchpad CC3200 SimpleLink WiFi** | Development board | Prototyping, Hobbyists, DIY | ti.com |
| **Ubidots Cloud** | IoT Platform | Device Management, Analytics | ubidots.com |
| **U-Blox ODIN-W2** | Development board modules | Prototyping, Connectivity, Networking | u-blox.com |
| **Ubuntu Snappy Core** | IoT Platform | App Development | ubuntu.com |
| **UiMagician** | IoT Platform | App Development | vscp.org |
| **VectorCAST by Vector Software** | Testing Platform | DevOps, Automated Testing | vectorcast.com |
| **Verdigris** | IoT Platform | Analytics | verdigris.co |
| **VersaSense** | Sensors | Home Automation | versasense.com |
| **Vortex by PrismTech** | Connectivity Middleware | Device Management | prismtech.com |
| **VSCP** | Messaging Middleware | Connectivity | vscp.org |
| **WasteOS by Compology** | Sensors | Logistics, Smart City | compology.com |
| **Wifithing** | IoT Platform, Development Board | Prototyping, Industrial IoT | wifithing.com |
| **Windows 10 IoT Core** | IoT Platform | Prototyping, Hobbyists, DIY | developer.microsoft.com |
| **Wio Link** | Development board | Prototyping, Hobbyists, DIY | seeedstudio.com/ |
| **Wiring S** | Development board | Prototyping, Hobbyists, DIY | wiring.org.co |
| **wot.io** | Connectivity Middleware | Device Management, Connectivity | wot.io |
| **WSO2 IoT Server** | Connectivity Middleware | Device Management, Connectivity | wso2.com |
| **Wyliodrin** | IDE, IoT Platform | Prototyping, Hobbyists, DIY | wyliodrin.com |
| **Xively by Logmein** | IoT Platform, Connectivity Middleware | Device Management, App Development | xively.com |
| **Yantra Cloud by ConnectM** | M2M/IoT Platform | Home Automation, Logistics | connectm.com |
| **Zatar by Zebra Technologies** | IoT Platform | Prototyping, Device Management, Healthcare, Industrial IoT | zatar.com |
| **Zonoff** | IoT Platform | Device Management, Analytics, Industrial IoT, Home Automation | zonoff.com |

# DIVING DEEPER

## INTO THE INTERNET OF THINGS

### TOP 10 #IoT TWITTER FEEDS

 @BuildingIoT
 @Doug_Laney
 @theIoT
 @JoeSpeeds
 @postscapes
 @AmyxIoT
 @BetweenMyths
 @haiyan
 @spourdalac
 @marc_in_london

### DZONE IoT-RELATED ZONES

**IoT Zone**

dzone.com/iot

The Internet of Things (IoT) Zone features all aspects of this multifaceted technology movement. Here you'll find information related to IoT, including Machine to Machine (M2M), real-time data, fog computing, haptics, open distributed computing, and other hot topics. The IoT Zone goes beyond home automation to include wearables, business- oriented technology, and more.

**Integration Zone**

dzone.com/integration

Enterprise Integration is a huge problem space for developers, and with so many different technologies to choose from, finding the most elegant solution can be tricky. The EI Zone focuses on communication architectures, message brokers, enterprise applications, ESBs, integration protocols, web services, service-oriented architecture (SOA), message-oriented middleware (MOM), and API management.

**Mobile Zone**

dzone.com/mobile

The Mobile Zone features the most current content for mobile developers. Here you'll find expert opinions on the latest mobile platforms, including Android, iOS, and Windows Phone. You can find in-depth code tutorials, editorials spotlighting the latest development trends, and insight on upcoming OS releases. The Mobile Zone delivers unparalleled information to developers using any framework or platform.

### TOP IoT REFCARDZ

**Getting Started With Industrial Internet**
dzone.com/refcardz/getting-started-with-industrial-internet

**Getting Started With MQTT**
dzone.com/refcardz/getting-started-with-mqtt

**AMQP Essentials**
dzone.com/refcardz/amqp-essentials

### TOP IoT WEBSITES

**Internet of Things Awards**
iotawards.postscapes.com

**The IoT Council**
theinternetofthings.eu

**IEEE Internet of Things**
iot.ieee.org

### TOP IoT RESOURCES

**IoT Journal**
iot-journal.weebly.com

**IoT Adoption Survey**
bit.ly/28KECYu

**Internet of Things Beyond the Hype**
bit.ly/28LhhIK

# GLOSSARY

**APPLICATION AGENTS** Help address the lack of overhead for end-to-end, peer-to-peer networking in IoT architecture by their presence in the propagator nodes in an enterprise. They move intelligence to the edge of the network to help manage traffic, allow a real-time response to changing IoT conditions, and provide local client services.

**CHIRPS** Lighter, purpose-built protocols that allow the "things" in IoT to communicate and interchange. Built for the machine-to-machine communication of IoT, they are efficient, extensible data frames that have an open-source structure, private data fields, and a simple checksum.

**CONNECTED DEVICES** Components that make up the Internet of Things. Many have built-in sensors and/or actuators and collect data to help users or other devices make informed decisions and monitor or affect outside events.

**CONNECTIVITY PROTECTION** A part of the Edge Layer that serves to ensure that the device connectivity doesn't fail if there is a network failure or an unreliable connection.

**DATA FILTRATION** A part of the Edge Layer that reduces the amount of transmitted information, but retains the meaning of it.

**DEVICE AGNOSTIC CONTROL** Part of the Edge Layer that provides site abstraction to allow the server and/or cloud application to be agnostic to the device implementation it controls.

**EDGE LAYER** An architectural shift in IoT that breaks the norm of the traditional client-server model. This is the first layer of connectivity for devices to connect to before going to the server. Responsible for the local connectivity of devices and for managing the data collection and connection to this server.

**GREEN COMPUTING PARADIGMS** A practice of energy efficiency to ensure that developers conserve the amount of energy consumed when processing and transferring data.

**HAZE COMPUTING** A dynamic model for analytics applications wherein an application at the data source analyzes a pooled view of resources for the local and global compute available across the cloud, edge, and device layers. This information informs how and where data analytics take place.

**HEAD MOUNTED DISPLAYS (HMDS)** A wearable device in the form of goggles or a helmet that is used with virtual reality systems. This kind of device has several monitors allowing the user to see images in 3D. They also have trackers that respond to head movements to create a virtual environment seen only by the wearer.

**INDUSTRIAL INTERNET** The integration of machine learning, big data technology, sensor data, and machine-to-machine communication automation. This is done with the knowledge that the Internet of Things will be scaled and driven by enterprises. The idea is that smart machines can more accurately capture and communicate data to help corporations find problems sooner and increase overall efficiency.

**INTEGRATOR** The "tree trunk" of network architecture that performs the big data functions to provide a higher-level analysis of human interaction for near-edge analytics and broader-scope analysis and control.

**INTERNET OF THINGS (IoT)** A network of objects (such as sensors and actuators) that can capture data autonomously and self-configure intelligently based on physical-world events, allowing these systems to become active participants in various public, commercial, scientific, and personal processes.

**IoT EDGE GATEWAY** The connecting factor between device analytics and cloud data processing and analytics.

**LOW-POWER DEVICES** Electronics that have been designed to use less electric power than traditional devices. These are necessary to the future success of IoT because, as sensors become more advanced, devices need to be able to operate for longer periods of time without relying on manual maintenance or loss of data.

**MACHINE-TO-MACHINE (M2M)** Refers to a network setup that allows connected devices to communicate freely, usually between a large number of devices; M2M often refers to the use of distributed systems in industrial and manufacturing applications.

**MESSAGING PROTOCOLS** The way information is transferred and communicated amongst devices, the cloud, and data storage. Different protocols are used for different results.

**PROPAGATOR** The "leaves" of the network architecture tree that are serviced by intermediate branch network elements. They manage message routing and protocol translation services.

**REAL-TIME OPERATING SYSTEM (RTOS)** Designed to guarantee the completion of a task within a certain time constraint. Often used in safety-critical systems and when building IoT devices.

**SENSOR NETWORK** A group of sensors with a communications infrastructure intended to monitor and collect data from multiple locations.

**SITE-LEVEL MANAGEMENT** Allows site-level arrangement across devices from different vendors using dissimilar protocols.

**WEARABLES** Connected devices that can be equipped with different types of sensors and are worn on a person's body. They are meant to monitor, collect, and quantify data about a person's life and environment, and allow them to interface with that data.


ThingWorx is purpose-built for the Internet of Things, with tools, APIs, and marketplace extensions that lower costs, increase developer productivity, and speed time-to-market.

With the ThingWorx IoT Platform, you have access to a powerful development engine and a broad set of innovative technologies that extend the power of the IoT:

- **CONNECT to any Thing**
- **CREATE Apps for all Users**
- **ANALYZE Machine Data**
- **EXPERIENCE all Things through Augmented Reality**

Learn more about how the ThingWorx IoT Platform is the right choice to power your organization's digital transformation.

**www.thingworx.com/go/IoTGuide**

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