NUVATION ENGINEERING

Designing IoT Sensor Networks

- Low-power sensor design
- Sensor network architecture
- Sending data to the cloud
- User control systems

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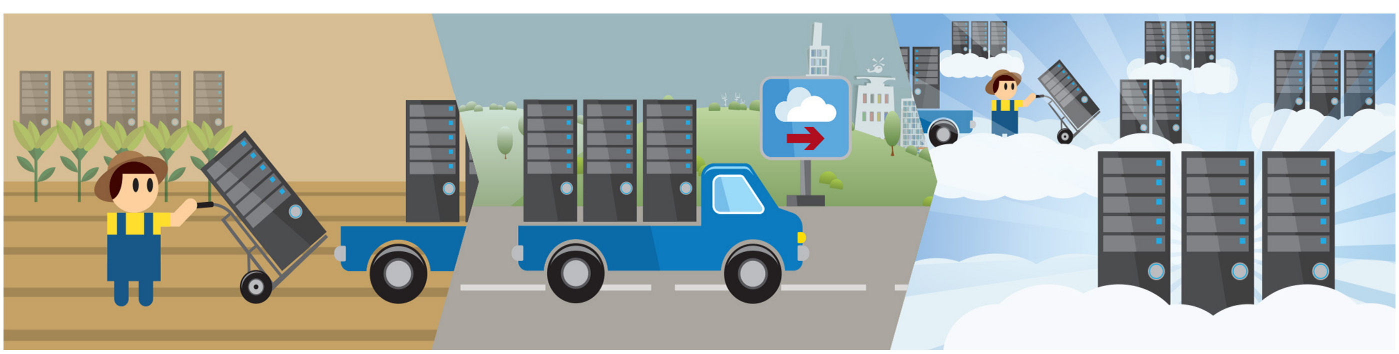
1 The Birth of the Internet of Things

Before its recent rebranding as "IoT," the Internet of Things concept began emerging with devices like the now famous Coke® machine at Carnegie Mellon University (CMU), which since the 1980s has been self-monitoring its internal stock of soft drinks. It monitors how long each bottle has been cooling in the machine and stores this information on a server for access via faculty and students' computer terminals before they make the long trek to their beloved fuelling station.[1]

Despite its decades-long heritage, the Carnegie Mellon University Coke machine still stands as an ideal example of the value that IoT technologies can bring to today's businesses and consumers. For CMU students and faculty, the decision to take a break from the books to embark on a quest for caffeine and sugar has been informed for nearly three decades by IoT-driven data regarding the current coldness and available supply of soft drinks in the vending machine.

Those responsible for refilling the machine could if they wished, leverage this information to serve a "just in time" supply management process. The business owners could also collect aggregated usage data to better understand customer consumption patterns, forecast sales and predict stocking requirements in any given week, month, or fiscal quarter.

Fast forward to today (that Coke machine at CMU has had a makeover or two since the eighties, but is still transmitting data, and now also reports on M&M's®), and we find modern society operating within an information technology infrastructure that is so ideally architected to support IoT that conspiracy theorists could argue an intelligent design has been driving us towards it. Such theorists would not be far off; for over a decade technology providers have been striving to create devices that operate on shared platforms and can "talk to each other." Such technology convergence[2] has in part led to the semantic relocation of data storage centers from "server farms" to "the cloud," an appropriately undefined "anywhere" through which data and applications can be stored, accessed, and shared from anywhere in the world.



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2 A Sensor-Based IoT Communication Architecture

IoT solutions can come in many flavors and any concrete explanation of how a particular business can leverage a collection of Internet-connected devices would require insight into that specific business context. However with even a basic understanding of the core components of IoT architectures and their functions it becomes very easy to begin visualizing a range of possible deployments.

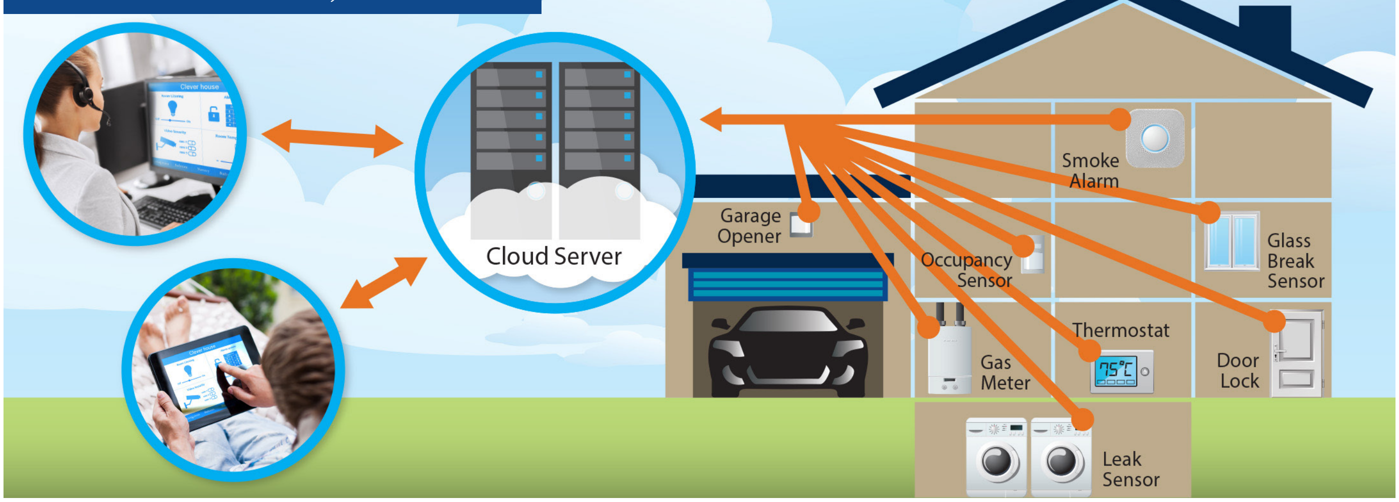
IoT architectures are usually comprised of a set of sensors that collect different types of data and transmit them to a "base station" that uploads the data to the cloud. From there it can be accessed by consumers and/or businesses as actionable intelligence. While there are IoT architectures that leverage ubiquitous computing devices such as smartphones as either "base stations" or "sensors," this article will focus on the ones that employ actual sensors to detect certain conditions or states (e.g. movement, temperature, moisture, et al) and present this information to businesses in ways that enable them to be more responsive, lower operating costs, gain a competitive advantage, and increase efficiency.

A. Business Impacts

Sensor-based networked communications architectures enable businesses to deploy IoT platforms and monitor the status of their devices or other equipment in order to:

- Reduce workforce costs associated with manual monitoring methods.
- Improve customer satisfaction and retention by providing highly proactive customer service without increasing costs.
- Reduce equipment maintenance costs through early detection of equipment failures and device maintenance issues.
- Cost-efficiently extend product life cycles by remotely pushing out software/firmware updates to multiple devices across a wide geographic area.

A Home Automation and Security IoT Architecture



B. Sensors as Iot Enablers

Sensor-based IoT platforms can automate the collection and reporting of business-critical information such as inventory and supply shortages, equipment malfunctions, or specific behaviors and actions. For example, sensors that measure temperature, air flow, and moisture can be installed throughout a building and send data to a central monitoring station from which HVAC controls can be adjusted to improve the comfort of occupants while reducing energy and maintenance costs. Devices such as water fountains, food dispensers, parking lot security systems, and other facilities infrastructure can include sensors in their design to continuously monitor and report on their status. Municipal infrastructures can leverage IoT technologies to identify issues requiring resolution (e.g. pipes leaking underground) that may have otherwise become apparent only after they had caused significant damage. Warehousing and logistics organizations can drastically reduce or eliminate accidentally lost or misdirected shipments by including RFID tags with shipments and locating inventory via wireless sensors in buildings and shipping containers.

Such data can enable businesses to become aware of issues that require attention before they impact the customer or undermine the operation of dependent systems. In addition, historical IoT data can be used to make key business planning and forecasting decisions without requiring labor-intensive data collection and integration of information from disparate sources.

Nuvation IoT Project : HOME MONITORING SENSOR

- Wireless sensor developed by Nuvation Engineering to measure temperature and detect room occupancy.
- Passive infrared (PIR) sensor for motion detection
- Thermistor for temperature sensing
- Custom radio protocol improves security and battery life
- Operates in the 868/915 MHz ISM/SRD radio band

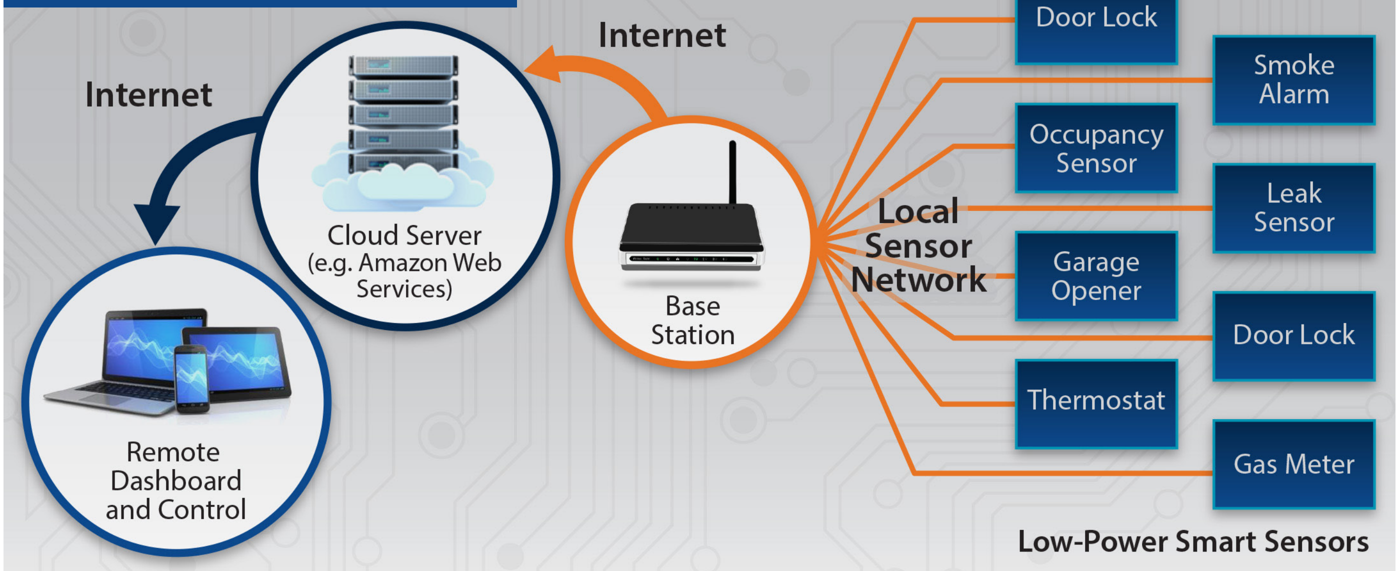
C. The IoT System Architecture

A typical sensor-based IoT architecture consists of the following:

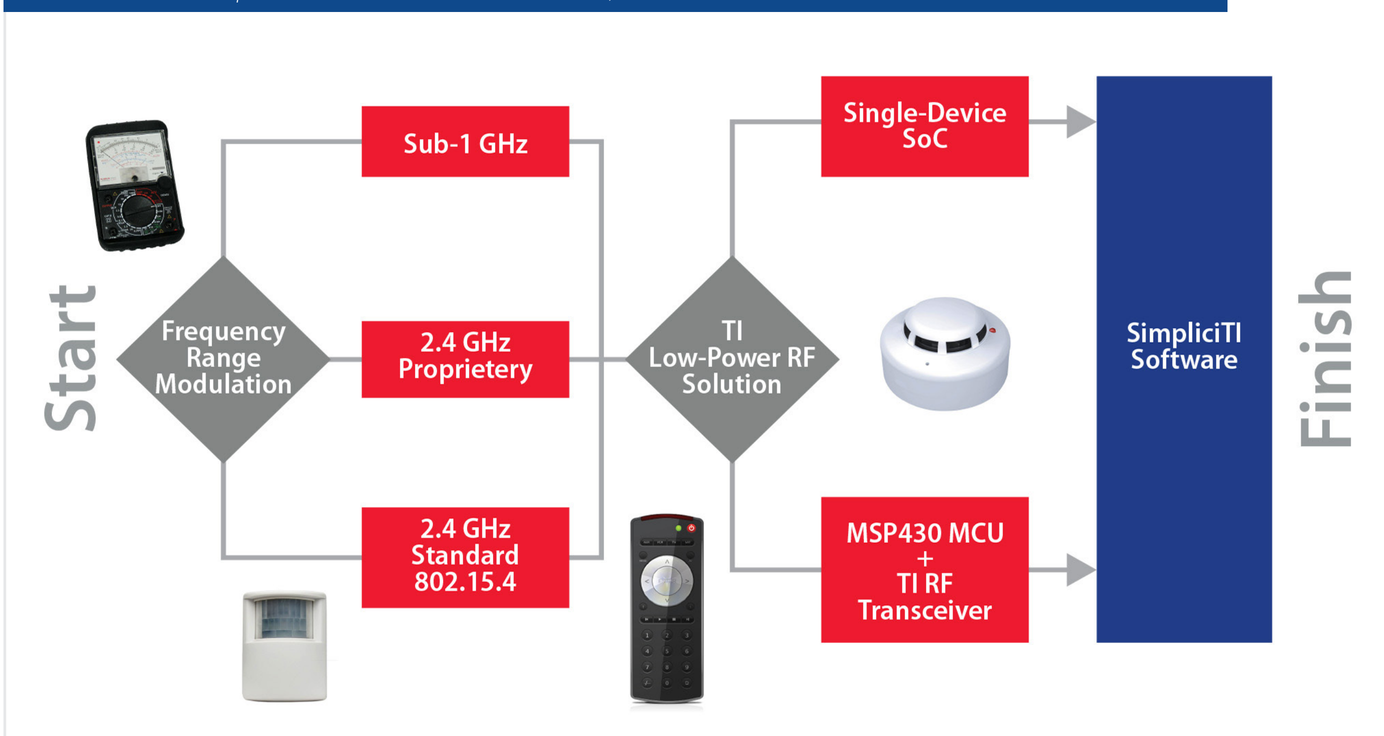
LOW-POWER SMART SENSORS (a.k.a. "EDGE DEVICES") – The smart sensor, or "edge device" (so named because these data collectors sit on the outer edge of the network) collects the granular data required by businesses, individuals, and intelligent systems. Many of today's sensors can operate on battery power to support wireless installation and communications, with battery life that can last months or even years. They generally achieve this through "smart" power management, i.e. going into ultra-low power states until they sense that a certain condition has occurred. An example of this could be a water sensor that only transmits information when water is detected. Nuvation Engineering, for example, developed an ultra-low power and high-sensitivity acoustic monitoring sensor platform to detect leaking pipes. It uses a low-power Texas Instruments (TI) MSP430 microcontroller and takes readings from microphones or piezoelectric transducers.

LOCAL SENSOR NETWORK – There are many options available to connect locally networked sensors to a base station, and low power consumption is usually a key requirement. RF (Radio Frequency) and BluetoothTM Smart are popular alternatives to the more power-hungry Bluetooth® 2.1 and Wi-Fi®. For example, Nuvation developed a low-power wireless connection for previously "dumb" but now made "smart" building infrastructure equipment using TI's SimpliciTITM network protocol for Sub-1 GHz, 2.4 GHz and IEEE 802.15.4 RF ICs.

A Sensor-Based IoT System Architecture



Texas Instruments SimpliciTITM Network Protocol for Sub-1 GHz, 2.4 GHz and IEEE 802.15.4 RF ICs



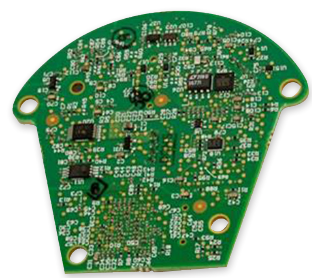
TI SimpliciTITM is a low-power RF protocol aimed at simple, small RF networks. This open-source software is an excellent start for building a network with battery-operated devices using one of TI's low-power RF System-on-Chips (SoC) or the MSP430 ultra-low-power MCU and a TI RF transceiver.

THE BASE STATION - The base station is the bridge between the sensor network and the cloud. This device is generally powered via an AC connection and supports more advanced data processing and transmission functions. The base station collects all the data transmitted by the sensors and can also push periodic firmware updates to them. It collects data from the local sensor network, "decides" what information is actionable business intelligence, and uploads that information to the cloud server via an Internet or cellular network connection. The base station can be populated with both Wi-Fi and cellular options as fallback methods of communication.

An example of this "decision-making" intelligence can be found in an IoT-supported home security system Nuvation developed for a client. When the security system is armed and a camera-enabled motion sensor is triggered, the base station sends a message to the homeowner's smartphone, warning that an alarm has been triggered, identifying which sensor triggered it in which room, and informing the customer that the monitoring station will be notified after thirty seconds. Also, pictures of the room / monitored area that were taken immediately before, during, and after the motion detector was triggered are emailed to the homeowner.

In this example, two business objectives are achieved: first, prompt customer service – when the alarm is triggered, the homeowner is notified immediately and provided with pictures that may potentially reveal the exact nature of the security breach. This notification takes place more quickly than a human agent could have provided these services. Second, this base station-driven "30-second warning" prior to contacting the monitoring station reduces the alarm company's operating costs by minimizing the amount of times live operators must deal with false alarms.

Nuvation IoT Project :
FIRE HYDRANT MONITORING



Custom smart leak detector for monitoring fire hydrants, developed by Nuvation Engineering. Hydrants are connected through a proprietary mesh network.
Features:

- High-sensitivity acoustic monitoring
- Data logging and signal analysis
- Ultra low-power sensors

CLOUD SERVER – Cloud computing allows consumers and businesses to access massive amounts of computing power at extremely low costs by leveraging economies of scale. This eliminates the need to invest in and support expensive server hardware in-house.

The base station can send periodic "heartbeats" to the cloud server to let it know that the sensor network is alive and healthy. The server can also push down commands, configuration and software updates to the base station, and also support application-level system management and analytics software. As the business needs grow or shrink, a business can simply add or reduce their cloud computing resources without concern for equipment costs or hardware obsolescence.

One example of such a scalable data center solution is Amazon Web Services (AWS®). AWS is a cost-effective and scalable service that requires no upfront infrastructure investment and which minimizes latency by providing servers in any or all of ten regions around the world. Amazon also takes care of the backups and hardware failover as well as elastic load balancing to ensure that sensor networks of any scale will always be able to phone home.

From a development project perspective, cloud servers enable the IoT project team to cost-effectively begin implementing a complete end-to-end IoT solution right from the development phase of the project. The cloud computing environment used during development becomes the prototype, and the prototype becomes the final product, all on the same platform.

REMOTE DASHBOARD & CONTROL STATION – This component has been called different things by various IoT proponents, and is essentially the computing platform where data is converted into actionable business intelligence. In our security system example, the homeowner's smartphone also acts as a control station from which they can check the security status of the home, access any monitoring cameras, voice-chat with people within or outside the home, and turn the alarm system on and off. The control station on the business side would have more functionality, display more information, and can usually generate analytics as well. The core software can reside in the cloud and/or on the business site.

Nuvation IoT Project : SMART WATER FOUNTAINS

Smart water fountain networking hardware for large facilities, developed by Nuvation Engineering. Features:

- Fountains wirelessly communicate with base stations
- Base stations collect and transmit usage, filter, and system health information to the cloud via Ethernet
- Wireless communications use a low-power unlicensed band for improved security and power savings

Conclusion

It is clear that sensor-driven IoT architectures have been here long before the term "the Internet of Things" was a "thing." The IoT architecture described in this paper is not carved in stone by any means; for all the examples provided, a dozen others could operate differently, although usually with a similar underlying structure.

It is our hope that this article has cleared away some of the ambiguity surrounding IoT by explaining the basic architecture of a sensor-based network, and providing specific examples of how such a system can be deployed in a variety of business contexts. The Carnegie Mellon University Coke machine is a very simple example that has immediately measurable benefits. The home security system example is much more complex, but also provides much larger ROI by enabling a company to install a multi-sensor system in the home without drilling holes or running wires, reduce call center staffing requirements, and provide the homeowner with sophisticated personal control of the system from anywhere.

For a consultation on the type of IoT architecture that can be developed for your business, please contact **Nuvation Engineering.**

Nuvation IoT Project : HOME SECURITY SYSTEM

Home surveillance and automation system developed by Nuvation Engineering.

- Sensor equipment connects to a custom base station over Wi-Fi®
- Base station collects images, controls data from the sensors, and pushes them to a high-availability server
- Customers can view their data over a web portal and on their personal mobile devices

References

1. http://www.cs.cmu.edu/~coke/history_long.txt. Accessed June 8, 2015.

2. http://www.sjpub.org/sjp/sjp-221.pdf. Olawuyi J.O. , Mgbole Friday, "Technological Convergence" Science Journal of Physics, Volume 2012, Article ID sjp-221, 5 Pages, 2012. Accessed June 8, 2015.

About Nuvation

Nuvation Engineering is a North American product realization company that performs all aspects of electronic product development, from initial concept and design through to volume production. Our partnerships with leading semiconductor manufacturers and 18 years in electronic design and embedded software engineering enable us to deliver high-quality solutions to organizations quickly and cost-effectively.

Nuvation has delivered hardware and software solutions across all industries, ranging from consumer electronics through medical devices, defense & aerospace, industrial automation and battery management systems for large-scale energy storage platforms. Our success is due to a combination of engineering excellence, best practices in project management, and strong relationships with technology partners.

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