White Paper

How the Internet of Things Is Revolutionizing Healthcare

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Abstract

In the Internet of Things (IoT), devices gather and share information directly with each other and the cloud, making it possible to collect, record and analyze new data streams faster and more accurately. That suggests all sorts of interesting possibilities across a range of industries: cars that sense wear and tear and self-schedule maintenance or trains that dynamically calculate and report projected arrival times to waiting passengers.

But nowhere does the IoT offer greater promise than in the field of healthcare, where its principles are already being applied to improve access to care, increase the quality of care and most importantly reduce the cost of care. At Freescale, we're excited to see our embedded technologies being used in applications like telehealth systems that deliver care to people in remote locations and monitoring systems that provide a continuous stream of accurate data for better care decisions.

As the technology for collecting, analyzing and transmitting data in the IoT continues to mature, we'll see more and more exciting new IoT-driven healthcare applications and systems emerge. Read on to learn what's happening now—and what's on the horizon—for healthcare in the age of the IoT.

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There's no shortage of predictions about how the Internet of Things (IoT) is going to revolutionize healthcare by dramatically lowering costs and improving quality. But what we're seeing at Freescale is that it's already doing that. Wireless sensor-based systems are at work today, gathering patient medical data that was never before available for analysis and delivering care to people for whom care wasn't previously accessible. In these ways, IoT-driven systems are making it possible to radically reduce costs and improve health by increasing the availability and quality of care.

In this paper, we'll explore in greater depth the role of the IoT in healthcare delivery, take a close look at the technological aspects that make it a reality and examine the opportunities and challenges the IoT poses for healthcare today. We'll start with an introduction to the IoT—still a relatively new concept—but one with a growing number of practical applications across many industries.

These topics are of vital interest to Freescale, where we develop and manufacture embedded technologies for use throughout IoT-driven healthcare systems, including:

• Sensors that collect patient data

• Microcontrollers that process, analyze and wirelessly communicate the data

• Microprocessors that enable rich graphical user interfaces

• Healthcare-specific gateways through which sensor data is further analyzed and sent to the cloud

First Things First: Understanding the IoT

IoT-related healthcare systems today are based on the essential definition of the IoT as a network of devices that connect directly with each other to capture and share vital data through a secure service layer (SSL) that connects to a central command and control server in the cloud. Let's begin with a closer look at what that entails and what it suggests for the way people collect, record and analyze data—not just in healthcare, but in virtually every industry today.

The idea of devices connecting directly with each other is, as the man who coined the term Internet of Things puts it, "a big deal."[1] As Kevin Ashton explained a decade after first using the phrase at a business presentation in 1999, "Today computers—and therefore, the Internet—are almost wholly dependent on human beings for information. The problem is, people have limited, time, attention and accuracy—all of which means they are not very good at capturing data about things in the real world."[1] The solution, he has always believed, is empowering devices to gather information on their own, without human intervention.

The emergence of the IoT, in which devices connect directly to data and to each other, is important for two reasons:

1. Advances in sensor and connectivity technology are allowing devices to collect, record and analyze data that was not accessible before. In healthcare, this means being able to collect patient data over time that can be used to help enable preventive care, allow prompt diagnosis of acute complications and promote understanding of how a therapy (usually pharmacological) is helping improve a patient's parameters.

2. The ability of devices to gather data on their own removes the limitations of human-entered data—automatically obtaining the data doctors need, at the time and in the way they need it. The automation reduces the risk of error. Fewer errors can mean increased efficiency, lower costs and improvements in quality in just about any industry. But it's of particular interest/need in healthcare, where human error can literally be the difference between life and death.

IoT Building Blocks Emerging Everywhere

Even though only "1 percent of things are connected today,"[2] according to Joseph Bradley, general manager of Cisco Consulting Services, businesses across a variety of industries are establishing the building blocks of the IoT infrastructure. Here are a few examples:

- **Home and building automation:** Digital marketer Lauren Fisher points to the Nest Learning Thermostat, which takes data about the home environment and owners' temperature preferences and programs itself to operate efficiently within the context of that information.[3] This technical framework provides energy providers with the connectivity to better manage the energy grid.

- **Automotive design and manufacturing:** Mobile virtual network operator Alex Brisbourne describes how the automotive industry is increasingly designing automated applications into vehicles to provide maintenance monitoring, fuel and mileage management, driver security and other capabilities that cost little to integrate but have significant earning potential.[4] The addition of a cloud-based server to analyze the data and automatically act on it—automatically scheduling a maintenance appointment at the appropriate time, for example—would move this further in the direction of the IoT.

- **Public transportation/smart cities:** Technology writer Martyn Casserly cites the London iBus system, which "…works with information from over 8,000 buses that are fitted with GPS capabilities alongside various other sensors which relay data about the vehicle's location and current progress,"[5] so bus stop signposts can display details of a bus's impending arrival.

IoT concepts have already been adopted in areas such as energy (e.g., smart lighting, smart grid) and industrial automation. According to a report in eWeek2 about a Cisco conference call with journalists, "…as more connections are made, the value to businesses and the global economy will only go up." The eWeek story describes a Cisco vision that goes beyond the IoT to IoE, or the Internet of Everything. This is what Cisco sees as a system of connections that includes not only devices, but also people, data and processes—"…essentially whatever is connected to or crosses over the Internet." Cisco expects the IoE to be worth $14.4 trillion to the global economy by 2020.

But, that's another story. Let's get back to the IoT to take a look at how it's being used in healthcare today and explore how it's changing healthcare for the better.

IoT in Action in Healthcare

The IoT plays a significant role in a broad range of healthcare applications, from managing chronic diseases at one end of the spectrum to preventing disease at the other. Here are some examples of how its potential is already playing out:

- **Clinical care:** Hospitalized patients whose physiological status requires close attention can be constantly monitored using IoT-driven, noninvasive monitoring. This type of solution employs sensors to collect comprehensive physiological information and uses gateways and the cloud to analyze and store the information and then send the analyzed data wirelessly to caregivers for further analysis and review. It replaces the process of having a health professional come by at regular intervals to check the patient's vital signs, instead providing a continuous automated flow of information. In this way, it simultaneously improves the quality of care through constant attention and lowers the cost of care by eliminating the need for a caregiver to actively engage in data collection and analysis.

An example of this type of system is the **Masimo Radical-7®**, a health monitor for clinical environments that collects patient data and wirelessly transmits for ongoing display or for notification purposes. The results provide a complete, detailed picture of patient status for clinicians to review wherever they may be. The monitor incorporates Freescale technology in the form of an i.MX applications processor with enhanced graphics capabilities that enables the extremely high-resolution display of information, as well as a touch-based user interface that makes the technology easy to use.

- **Remote monitoring:** There are people all over the world whose health may suffer because they don't have ready access to effective health monitoring. But small, powerful wireless solutions connected through the IoT are now making it possible for monitoring to come to these patients instead of vice-versa. These solutions can be used to securely capture patient health data from a variety of sensors, apply complex algorithms to analyze the data and then share it through wireless connectivity with medical professionals who can make appropriate health recommendations.

Remote Patient Monitoring
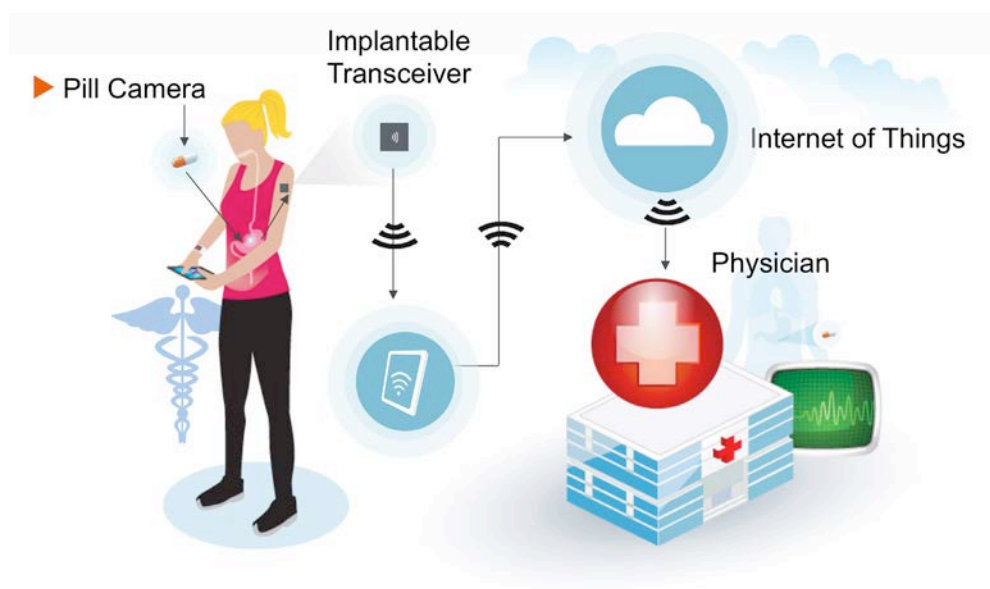
As a result, patients with chronic diseases may be less likely to develop complications, and acute complications may be diagnosed earlier than they would be otherwise. For example, patients suffering from cardiovascular diseases who are being treated with digitalis could be monitored around the clock to prevent drug intoxication. Arrhythmias that are randomly seen on an EKG could be easily detected, and EKG data indicating heart hypoxemia could lead to faster detection of cardiac issues. The data collected may also enable a more preventive approach to healthcare by providing information for people to make healthier choices.

An example of an enabling technology for remote monitoring is the **Freescale Home Health Hub reference platform**, which is built on Freescale i.MX applications processing technology and tightly integrates key capabilities—such as wireless connectivity and power management—in the telehealth gateway that enables collection and sharing of physiological information. The hub captures patient data from a variety of sensors and securely stores it in the cloud, where it can be accessed by those engaged in the patient's care. Data aggregation devices like this will soon become commonplace and will not only collect healthcare data but also manage other sensor networks within the home. Freescale's second-generation gateway manages data from smart energy, consumer electronics, home automation and security systems—in addition to healthcare.

Home Health Hub Reference Platform
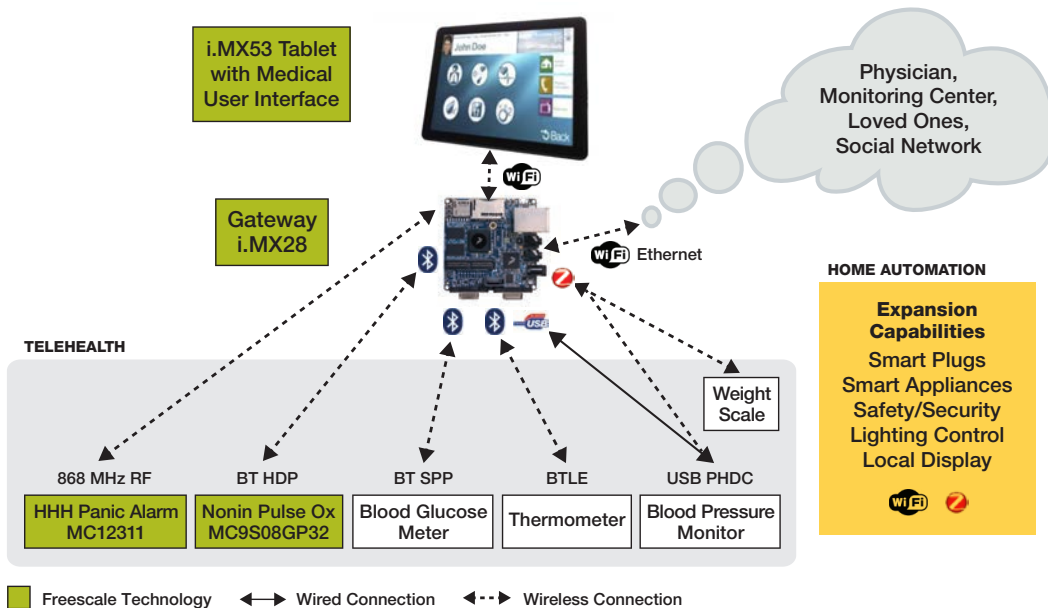
- **Early intervention/prevention:** Healthy, active people can also benefit from IoT-driven monitoring of their daily activities and well-being. A senior living alone, for example, may want to have a monitoring device that can detect a fall or other interruption in everyday activity and report it to emergency responders or family members. For that matter, an active athlete such as a hiker or biker could benefit from such a solution at any age, particularly if it's available as a piece of wearable technology.

Freescale technology has been incorporated into some solutions of this type. The **Sonamba daily monitoring solution**, aimed at the senior population, uses strategically placed sensors to monitor daily activities and report anomalies to care providers or family members via cell phone. Freescale provides applications processing and ZigBee®-based wireless connectivity for Sonamba. Freescale technology is also embedded in the **Numera Libris mobile personal health gateway**, which is designed to detect falls and provide the ability to manage one's health at home or away.

These are just a few examples of IoT-based healthcare solutions, and many more are emerging. But as one reporter has noted, "The real vision for the future is that these various smaller applications will converge to form a whole … Imagine if you are a relative of [a] patient who forgot their medicine. You receive the alert, are able to know their location, check their vital signs remotely to see if they are falling ill, then be informed by your car's navigation system which hospital has the most free beds, the clearest traffic route to get there and even where you can park."[5]

Enabling Technologies: Making the IoT in Healthcare Possible

The successful use of the IoT in the preceding healthcare examples relies on several enabling technologies. Without these, it would be impossible to achieve the usability, connectivity and capabilities required for applications in areas such as health monitoring.

Smart sensors, which combine a sensor and a microcontroller, make it possible to harness the power of the IoT for healthcare by accurately measuring, monitoring and analyzing a variety of health status indicators. These can include basic vital signs such as heart rate and blood pressure, as well as levels of glucose or oxygen saturation in the blood. Smart sensors can even be incorporated into pill bottles and connected to the network to indicate whether a patient has taken a scheduled dose of medication. For smart sensors to work effectively, the microcontroller components must incorporate several essential capabilities:

- **Low-power operation** is essential to keeping device footprint small and extending battery life, characteristics that help make IoT devices as usable as possible. Freescale, which has long offered low-power processing, is working now to enable completely battery-free devices that utilize energy harvesting techniques through the use of ultra-low-power DC-DC converters.

- **Integrated precision-analog capabilities** make it possible for sensors to achieve high accuracy at a low cost. Freescale offers this enabling technology within microcontrollers which contain analog components, such as high-resolution analog-to-digital converters (ADCs) and low-power op-amps.

- **Graphical user interfaces (GUIs)** improve usability by enabling display devices to deliver a great deal of information in vivid detail and by making it easy to access that information. Freescale's i.MX applications processors with high graphics-processing performance support advanced GUI development.

Gateways are the information hubs that collect sensor data, analyze it and then communicate it to the cloud via wide area network (WAN) technologies. Gateways can be designed for clinical or home settings; in the latter, they may be part of larger connectivity resource that also manages energy, entertainment and other systems in the home. The Freescale Home Health Hub reference platform includes a gateway component. Medical device designers can also use the platform to create remote-access devices for remote monitoring.

Wireless networking removes the physical limitations on networking imposed by traditional wired solutions like Ethernet and USB. Freescale offers microcontrollers that support wireless connectivity for devices based on popular wireless standards such as Bluetooth® and Bluetooth Low Energy (BLE) for personal area networks (PAN) used with personal devices and Wi-Fi® and Bluetooth for local area networks (LAN) in clinics or hospitals. That leads us to a key challenge for the IoT in healthcare: standards.

Connectivity Standards: Enabling IoT Devices to Work Together

Standards represent an inherent challenge for any environment in which a large number of complex devices need to communicate with each other—which is exactly the case for the IoT in healthcare. One analyst has described the "…greater standardization of communications protocols…"[6] as critical to advancing the adoption of the IoT.

Fortunately, standards organizations are working now to create guidelines for wireless communications between monitoring devices and with care providers. The **Continua Health Alliance**, of which Freescale is a member, is a coalition of healthcare and technology companies that was founded in 2006 to establish guidelines for interoperable personal health solutions. The organization has already published a set of specifications to help ensure interoperability. In the future, organizations that buy a Continua-certified device will have the assurance that it will connect with other certified devices in IoT-driven applications.

Continua's device standards are part of a larger standards environment that includes information technology standards established by the International Organization for Standardization (ISO) and engineering standards set by the Institute of Electrical and Electronics Engineers (IEEE®).

In wireless technology, IEEE standards for LANs define Wi-Fi (IEEE 802.11) and ZigBee (IEEE 802.15.4) networks. Standards for PANs include Bluetooth and BLE, as well as IEEE 802.15.4j and IEEE 802.15.6, which are the IEEE standards associated with the body area network (BAN). Standards for cellular networks include GSM/UMTS and CDMA. Proprietary wireless networks still play something of a role in healthcare environments in general and IoT applications in particular, but that role seems to be shrinking as the industry continues to move toward standards-based architectures.

IoT in Healthcare: The Time Is Now

The long-predicted IoT revolution in healthcare is already underway, as the examples in this paper make clear. And, those are just the tip of the proverbial iceberg, as new use cases continue to emerge to address the urgent need for affordable, accessible care. Meanwhile, we are seeing the IoT building blocks of automation and machine-to-machine communication continue to be established, with the addition of the service layer completing the infrastructure. Freescale is excited to be a part of this revolution by providing end-to-end processing and connectivity solutions for IoT-driven healthcare solutions, working toward establishing standards for these solutions and accelerating innovation for organizations eager to realize the benefits of the IoT in healthcare.

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