NI Trend Watch 2016

Insights Today. Innovations Tomorrow.

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When Everything is Connected, Anything is Possible

For nearly 40 years, NI has helped engineers and scientists solve the world's greatest engineering challenges by providing powerful, flexible platform-based systems that accelerate productivity and drive rapid innovation.

While our customers deliver hundreds of thousands of products to market and overcome innumerable technological roadblocks using NI tools, we know that their success depends on more than just having the right tools. It requires having the right information at the right time to make the right decisions when delivering groundbreaking new innovations to a world always eager for the "next big thing."

But what happens when the next big thing is a multitude of things outfitted with hundreds of thousands of sensors with new levels of embedded intelligence that gather massive amounts of Big Analog Data and transmit that data over hyperfast, wireless networks?

It's a future that's rapidly unfolding before our eyes, but it's also a trend that's been woven into the fabric of NI's expertise in test, measurement, and control for decades.

In fact, as a technology-driven company that invests more than 16 percent of our annual revenue in R&D, NI remains committed to ensuring that investment is deeply leveraged in the commercial technologies we adopt. This allows us to not only maintain close, strategic relationships with suppliers but also conduct frequent technology exchanges with key stakeholders to get their outlooks on upcoming technologies and investment strategies.

With this level of insight and deep knowledge of the technological advances happening across virtually every industry, NI is ready to help you make sense of what's next and how you can use it to solve your engineering challenges.

Eric Starkloff
Executive Vice President of
Global Sales and Marketing, NI

Prototyping Takes 5G From Concept to Reality

5G will undoubtedly evolve our wireless networks to heights never before imagined, but its advancement doesn't come without challenges.

Researchers must not only address the requirements of unprecedented wireless data rates but also find solutions for network latency and responsiveness while accommodating a thousandfold increase in capacity. And if all that weren't enough, service operators are demanding that these advancements consume less energy than existing infrastructure.

So how do we begin to solve these complex challenges? The answer lies in prototypes and, more specifically, the kind of 5G prototypes that enable wireless researchers to test experimental ideas using real systems in real-world scenarios. When done right, these 5G prototypes can lay the foundation for rapidly increasing an organization's time-to-market schedule.

Setting a New Standard

Recognizing the large amount of speculation regarding 5G networks, the world's standardization bodies, including the 3GPP, have recently begun to transition concepts into reality. Not surprisingly, the vision painted by IMT-2020, the NGMN, and the 3GPP is expansive. 5G researchers now must build the framework that will redefine our very existence—from automobiles and transportation systems to manufacturing, energy, healthcare monitoring, and more.

To do this, researchers are adopting new design approaches to help with the challenging task of defining, developing, and deploying 5G technologies within a random access network. Most acknowledge that conventional approaches to vetting 5G technologies take too long and incur significant costs. Therefore, building a prototype and a proof of concept earlier in the process enables faster commercialization. Noting the importance of research-enabling testbeds, National Science Foundation Program Director Thyaga Nandagopal, said, "A viable prototype is increasingly the critical element to determining success or failure of a particular concept."

Blazing a New Path Through Research

To expedite the time it takes to produce a working prototype, many researchers have adopted a platform-based design approach that embraces a unified design flow. It starts with math and simulation and then maps the algorithm in a system and working hardware.

Consider Samsung, which has built one of the world's first demonstrators of multi-antenna technology with a base station (BTS) that includes 32 antenna elements called Full-Dimension MIMO or FD-MIMO. FD-MIMO uses a 2D grid of antennas to create a 3D channel space. With FD-MIMO, service operators can place antenna grids at elevated positions such as buildings or poles and aim the antenna beams at users on the ground or in adjacent buildings to consistently deliver enhanced data rates.

Researchers at Lund University in Sweden have taken this multi-antenna concept to the next level with their Massive MIMO prototype. Massive MIMO increases the number of antennas in a cellular BTS to hundreds. Composed of low-cost technology, the grid of antenna elements focuses the energy directly at the user while

> “A viable prototype is increasingly the critical element to determining success or failure of a particular concept.”
>
> —**Thyaga Nandagopal**, Program Director, National Science Foundation

enabling the hundreds of antennas to more easily detect weak signals from mobile devices. Additionally, Massive MIMO uses linear coding techniques to simplify the processing at the BTS.

As more BTS antennas enhance the mobile user data experience, we can see how theory confirms that Massive MIMO may also dramatically reduce the power consumed by both the BTS and mobile devices. Because multiple low-cost BTS antennas transmit lower aggregate power than a monolithic approach, the power consumed by the BTS may be reduced by a factor of 10 or more.

Fundamentally, enhanced data rates and increased capacity are constrained by spectrum according to Shannon’s theory on channel capacity. More spectrum yields higher data rates, which help service operators accommodate more users. As such, service operators around the world have paid billions of dollars for spectrum to service their customers, yet the currently available spectrum below 6 GHz is almost tapped out. Researchers are now investigating the possibility of deploying cellular networks above 6 GHz, specifically in the mmWave bands.

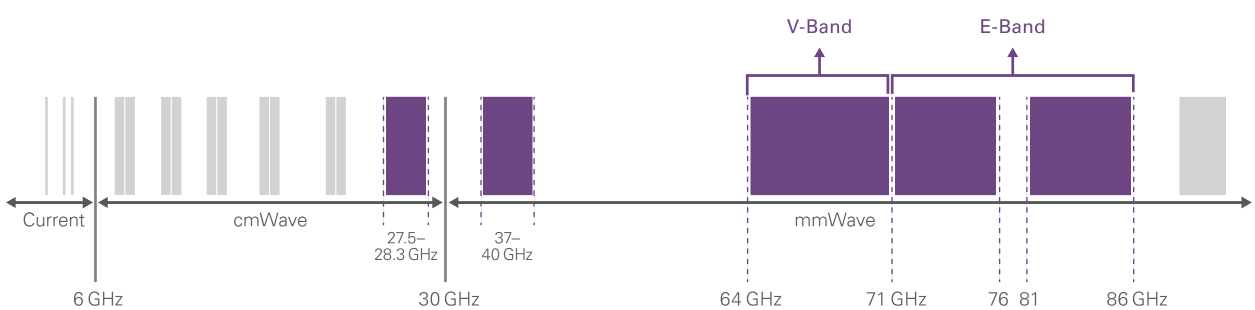
Worth noting is that the mmWave spectrum is plentiful and lightly licensed, meaning it is accessible to service operators around the world. Professor Ted Rappaport at New York University Wireless has been investigating mmWave as a possible evolutionary path for mobile networks since the mid-2000s. His pioneering channel measurement work has led researchers all over the world to reconsider their assumptions that mmWave mobile networks are either impractical or unfeasible.

Furthermore, researchers at Nokia Networks are also investigating mmWave technologies, and the preliminary results are encouraging. In 2015 alone, Nokia Networks demonstrated a fully working mmWave prototype that delivers the fastest rates ever recorded for mobile access. The Nokia Networks prototype composed of a BTS and a UE consistently streamed data at a rate of over 10 Gbps at 73.5 GHz. Nokia Networks’ achievement paints a promising future for mmWave and 5G.

The Future is Here

5G offers many exciting new developments to ultimately improve our lives through enhanced connectivity and unlock tremendous economic value. But for us to reap these benefits, researchers need a faster path to prototype. Traditional approaches have grown too expensive and time-consuming, and the world is growing impatient. A platform-based design approach can deliver these new developments faster, just as the researchers at places like Lund University, Nokia Networks, NYU Wireless, and Samsung are already demonstrating. It’s time to join this wave of innovation and see where it takes us next.

mmWAVE FREQUENCIES PROVIDE GREATER SPECTRUM OPPORTUNITY



Big Analog Data of the Future: From the Edge to the Enterprise

With the proliferation of sensing and networking technologies, adding measurements to systems has never been easier and more cost-effective.

In the midst of this explosion of engineering and measurement data, if companies don't have a sound data management strategy in place, a few years from now they'll be incapable of effectively dealing with and managing all of their data. Because of this, best-in-class measurement and analytics solutions must have two fundamental capabilities: (1) edge analytics and (2) smart enterprise management and analytics.

Pushing Measurement Analytics to the Edge

Over the past decade, the intelligence of data acquisition devices and sensors has drastically increased and become more decentralized, with processing elements moving closer to the sensor. One look at the many examples of acquisition systems and nodes integrating the latest silicon and IP from companies like ARM, Intel, and Xilinx proves as much. But in addition to measurement devices getting smarter, smart sensors have emerged that integrate the sensor, signal conditioning, embedded processing, and digital interface/bus into an extremely small package or system.

Given this trend, many scenarios now emphasize intelligence and advanced signal processing at the edge. Within asset monitoring applications, traditional measurement systems log every data point to disk, even when nothing substantial with the physical phenomena being measured is happening. This can result in gigabytes and potentially terabytes of data from thousands of deployed systems that need to be analyzed and sifted through offline.

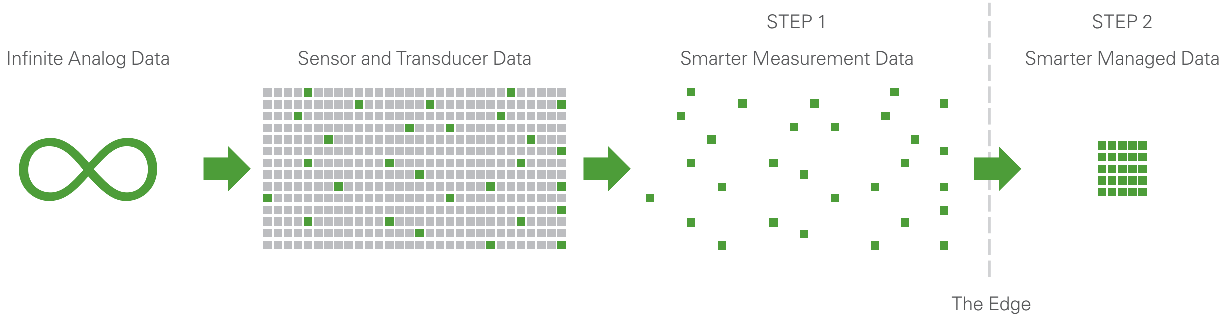
As processing moves closer to the sensor, innovation in measurement system software is required to efficiently push analytics to the edge. Future software for edge-based systems will be able to quickly configure and manage thousands of networked measurement devices and push a myriad of analytics and signal processing to those nodes. Going forward, companies must transition to smarter, software-based measurement nodes to keep up with the amount of analog data they'll be producing.

> "Analytics at the edge in IoT and other industrial solutions play critical roles in solving the Big Analog Data problem. Intelligent measurement nodes afford analysis of data inline and, in turn, accelerate meaningful results. It's all about time to insight from the big data."
>
> —**Dr. Tom Bradicich**, General Manager and Vice President, Hyperscale Servers and IoT Systems, Hewlett Packard Enterprise

Creating Smarter Enterprise Management and Analytics

Once the data is captured from smart systems, the next step is to push that data to the enterprise to effectively manage, consolidate, and perform large-scale analysis

SOLVING THE BIG ANALOG DATA CHALLENGE



With smarter measurement systems, you can embed more processing at the point of the acquisition and capture only the most critical data. An enterprise data management solution helps to ensure that you are getting the most critical data in front of the right people to make data-driven decisions faster.

on the data. An enterprise data management and analysis solution that can manage engineering data from numerous sources is paramount for getting the right data in front of the right people at the right time to make the right data-driven decisions. Two key considerations are properly documented data sets and smarter analysis.

Properly Documented Data Sets

To accurately perform analysis across multiple sources, all data sets should include consistent metadata, or descriptive information that describes why the test data was saved. Metadata can include information such as the test setup, test outcome, units of the measurement, and so on. According to the IDC, most companies document 22 percent of the data they collect, but they can analyze on average only 5 percent of their data. That is a lot of potentially critical data that is simply going unused. Companies that focus on standardizing metadata, which increases the amount of data they are able to automatically analyze, will see increased competitive advantages.

But before starting an implementation to standardize metadata, engineers must first agree on which metadata is important for their analysis. Best-in-class companies often include a project specification defining the metadata nomenclature and attributes collected. Applications should attempt to document as much of the agreed upon attributes at the point of acquisition. However, many companies are also adding attributes after the data has been collected by running automated checks and inserting attributes that are missing. This includes Jaguar Land Rover, which automated metadata quality checks and, within one year of developing and implementing an enterprise data management solution, estimates that it went from analyzing 10 percent of its data to now analyzing up to a staggering 95 percent of its data. The uniformity of its metadata allowed it to apply consistent and automated analysis mapped to defined attributes.

Smarter Analysis

According to Frost & Sullivan's September 2015 report on the Global Big Data Analytics Market for Test & Measurement, product development costs can be reduced by almost 25 percent, operating costs can be reduced by almost 20 percent, and maintenance costs can be reduced by 50 percent if big data analytics is applied for testing. Considering that analog data is the fastest growing and largest type of data that can be collected, finding new correlations and predicting future behaviors are key to maintaining a competitive edge.

To do this, companies that take measurements for research, design, and validation will need to drastically improve how they collect and analyze data on the edge and manage and analyze data within the enterprise to ensure they are leveraging it efficiently and making data-driven decisions. The sooner they do, the sooner they'll be turning better data into bigger returns.

It's About Time: Evolving Network Standards for the Industrial IoT

The Industrial Internet of Things (IIoT) promises a world of smarter, hyper-connected devices and infrastructure where electrical grids, manufacturing machines, and transportation systems are outfitted with embedded sensing, processing, control, and analysis capabilities.

Once networked together, they'll create a smart system of systems that shares data between devices, across the enterprise, and in the cloud. These systems will generate incredible amounts of data, such as the condition monitoring solution for the Victoria Line of the London Underground rail system, which yields 32 TB of data every day. This Big Analog Data will be analyzed and processed to drive informed business decisions that will ultimately improve safety, uptime, and operational efficiency.

Though much of this raw, unprocessed data is not time critical and can be passed between network layers and subsystems with little regard for latency or synchronization, there is an entire class of mission-critical, time-sensitive data that must be transferred and shared within strict bounds of latency and reliability. This includes critical control and fault detection data that must be processed, shared, and acted upon immediately, regardless of other network traffic.

Much of today's network infrastructure is not equipped to handle such time-sensitive data. Many industrial systems and networks were designed according to the Purdue model for control hierarchy in which multiple, rigid bus layers are created and optimized to meet the requirements for specific tasks. Each layer has varying levels of latency, bandwidth, and Quality of Service, making interoperability challenging and the timely transfer of critical data virtually impossible. In addition, today's proprietary Ethernet derivatives have limited bandwidth and require modified hardware.

To support the new capabilities of IIoT-enabled infrastructure, designers and end users alike need reliable, remote, and secure access to smart edge devices. Network technologies must evolve to satisfy the requirements of these next-generation industrial systems and radically advance the way we operate our machines, electrical grids, and transportation systems.

TSN: The Time is Now

Existing IT networks are defined by IEEE 802 standards, which specify requirements for different Ethernet layers and functions and ensure interoperability between devices. Today, industrial suppliers, IT vendors, and silicon providers are collaborating within IEEE 802 and the recently formed AVnu Alliance to update standard Ethernet protocols and provide bounded, low-latency data transfer for time-critical data in IIoT applications.

"Organizations like AVnu and the Industrial Internet Consortium are facilitating the expansion of Ethernet capabilities through standards. The broad market expansion of TSN will benefit numerous industries and applications and will be critical to achieving the vision of IoT with 50 billion connected devices."

—**Paul Didier**, AVnu Alliance Board Member and IoT Solutions Architect, Cisco

This next-generation standard, called Time-Sensitive Networking or TSN, addresses existing network shortcomings. The AVnu Alliance, working with companies such as Broadcom, Cisco, Intel, and NI, will drive the creation of an interoperable ecosystem through certification, similar to how the Wi-Fi Alliance certifies products and devices to be compatible with the IEEE 802.11 standard. The new TSN standard will provide numerous benefits, including the following:

Bandwidth—Large data sets from advanced sensing applications such as machine vision, 3D scanning, and power analysis can put a strain on network bandwidth. Proprietary Ethernet derivatives commonly used for industrial control today are limited to 100 Mb of bandwidth and half-duplex communication. TSN will embrace standard Ethernet rates and support full-duplex communication.

Security—Most of the lower-level field buses used today achieve security through air gap and obscurity. They are influenced by the automotive industry, for which air-gapped and closed CAN networks carry all the control and operational data. But recent security breaches have exposed the need to fully extend security into the critical lower levels of control infrastructure. TSN protects critical control traffic and incorporates top-tier IT security provisions, while segmentation, performance protection, and temporal composability can add multiple levels of defense to the security framework.

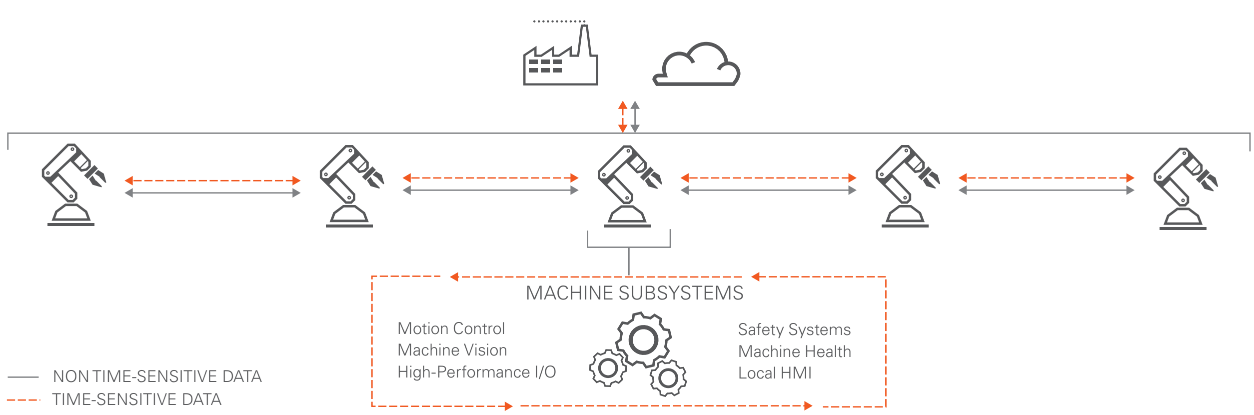
Interoperability—By using standard Ethernet components, TSN can integrate with existing brownfield applications and standard IT traffic to improve ease of use. TSN inherits many features of existing Ethernet, such as HTTP interfaces and web services, which enable the remote diagnostics, visualization, and repair features common in IIoT systems. As an added benefit, leveraging standard Ethernet chipsets drives component cost down by virtue of high-volume, commercial silicon.

Latency and Synchronization—TSN prioritizes the low-latency communication required for fast system response and closed-loop control applications. It can achieve deterministic transfer times on the order of tens of microseconds and time synchronization between nodes down to tens of nanoseconds. To ensure reliable delivery of this time-critical traffic, TSN provides automated configurations for high-reliability data paths, where packets are duplicated and merged to provide lossless path redundancy.

The Future Will Arrive on Time

As IIoT adoption continues, increased amounts of data and widely distributed networks will require new standards for sharing and transferring critical information. Just as an ambulance or a fire engine receives priority among other traffic during an emergency, the TSN standard ensures that critical, time-sensitive data is delivered on time over standard network infrastructure. Welcome to life in the fast lane with the IIoT.

STANDARD IT AND TIME-SENSITIVE DATA CONVERGE TO CONNECT DEVICES AND THE ENTERPRISE



Testing the Big Bang of Smart Devices

Imagine today's typical test manager, awash in an alphabet soup of wireless protocols and sensors upon sensors.

Thanks to the proliferation of smart devices in the Internet of Things (IoT), it's a circumstance not unlike the overwhelming sense of wonder and bewilderment that ancient Greek astronomer Ptolemy must have felt when gazing up at a sky full of stars on a clear winter's night, trying to rationalize the vast tableau before him.

But just as we wouldn't critique early astronomers and philosophers for thinking stars revolved around Earth, we shouldn't fault test managers for seeing the IoT from a device-under-test (DUT)-centric view. From this vantage point, the IoT can easily seem like an insurmountable 50-billion-device challenge for any test organization. But when we apply what we now know about astronomy, we begin to see the expected universe of smart devices as systems of systems based on a few core elements that orbit a core architecture. By developing a test strategy with this architecture-centric perspective, your organization will be prepared to meet the challenges and opportunities of the IoT and will be well positioned to capitalize on the expected $19 trillion business opportunities it represents.

Survival of the Smartest

The three core elements at the nucleus of most smart devices are battery power, wireless connectivity, and sensors. Be it a smart thermostat, fitness tracker, or smartphone, the "smart" devices of tomorrow will always have sensors for interacting with the world around them, a rechargeable battery for untethered operation, and various modes of wireless connectivity to send and receive information from the Internet and other devices around them.

Instead of designing a unique test system for each unique DUT, test leaders must design a smart test system that can adapt to and test all smart devices. Mino Taoyama, vice president of manufacturing, operations, and quality at Intel Corporation, and his team are tackling this problem head on. "With wearables, choice is a necessity because not everyone has the same taste in style," he said. "However, when testing wearables, choice results in a high degree of product mix. At Intel, a single manufacturing line might produce thousands of different models of a fashion product in a year. The high mix requires that test systems be flexible enough to test a wide range of products and transition between them quickly. Our test systems are designed to handle a superset of the test needs of any one product—from supporting multiple wireless standards to mixed-signal testing."

Testing a sensor requires the ability to reproduce physical stimuli often with other types of sensors or transducers. Testing a battery requires the ability to source, sink, and measure power. Testing wireless communication requires the ability to both generate and analyze RF signals. Add up this laundry list of functionality and it's not hard to imagine a fully stacked, incredibly expensive rack of instrumentation. But thanks to Moore's law, test instrumentation can now benefit from the same embedded technology that's flooding the market with smart devices of all shapes and sizes.

It stands to reason, however, that testing an accelerometer is not the same as testing a force sensor, or that testing a Bluetooth transceiver is not

> “Our test systems are designed to handle a superset of the test needs of any one product—from supporting multiple wireless standards to mixed-signal testing.”
>
> —**Mino Taoyama**, Vice President of Manufacturing, Operations, and Quality, Intel Corporation

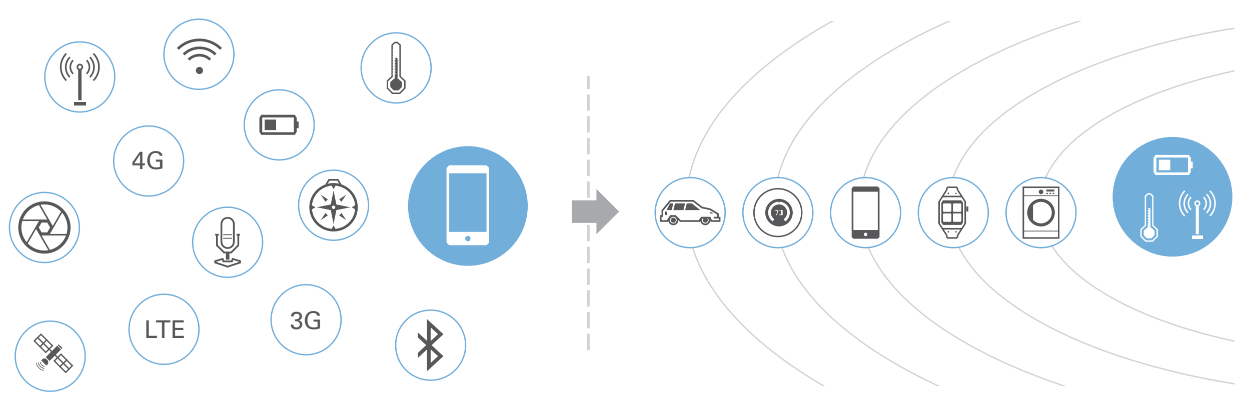
the same as testing a cellular antenna. Given this, how can test systems truly adapt? Again, the secret comes from looking at a smart device. A tablet and a fitness tracker both have an accelerometer within, but the accelerometer plays a very different role for each device. In a tablet, it’s used to sense how the user is holding the device and then orient the screen accordingly. But in the fitness tracker, the accelerometer is used to count the steps that the user takes throughout the day. The secret ingredient that spans across each? Software.

A Sense of Scale

Just as a smartphone’s functionality can be extended by apps and firmware updates, the functionality of a smart, software-defined test system can be extended and modified by software to keep pace with rapidly evolving device functionality. With a forward-looking investment in a hardware platform that can be easily upgraded to test the latest protocols, it’s easy to see how a test system can economically evolve at the speed of software and reverse the trend of rising test costs.

Astronomy has evolved since Ptolemy took his first look at the sky and proposed the geocentric model. Nicolaus Copernicus made a bold move by proposing that Earth and other planets revolved around a larger and much brighter mass: the sun in a heliocentric model. By recognizing the core elements of the universe of smart devices, we can gain the proper perspective necessary to scale system development and move beyond a collection of tools to a scalable strategy that brings unity to our understanding of the test industry.

ONE TEST STRATEGY PER DUT VERSUS ONE TEST ARCHITECTURE FOR ALL DUTS



The Consumerization of Software and How it Will Never be the Same

In a marketplace that's rapidly demanding convergence, and the best of all possible worlds, it's up to today's software vendors to answer the call.

Back when pocket protectors were both functional and fashionable (an engineer can dream, right?), engineering software and consumer software were radically different—not just because of the people who used them but also because of the inherently unique user experiences they provided.

But what happens when an unstoppable force (consumer software) meets an immovable object (engineering software)? In a marketplace that's rapidly demanding convergence and the best of all possible worlds, it's up to today's software vendors to answer the call.

The Evolution of Consumer Software

From right-click functionality to Microsoft's introduction of the ribbon, consumer software has long defined the user experience standards and expectations that most vendors follow. But with the recent explosion of beauty and simplicity across the general consumer market, expectations have changed.

Consider the iPhone, first introduced in 2007 and unanimously hailed as an inflection point in the software market for its seamless integration of gestures, single-button interfaces, aesthetically pleasing graphics, and fluidly simple community and purchasing experiences. Its sleek, modern graphics introduced animations, fades, and zooms that replaced the floating windows and unorganized tiling of traditional single screens. Its connected community and purchasing experience exposed a new world of extensibility by providing an interface to additional functionality not offered by the primary vendor. And its handprint on society became so indelible that even our youngest generations walk up to desktop monitors and expect to interact with it at a tactile level.

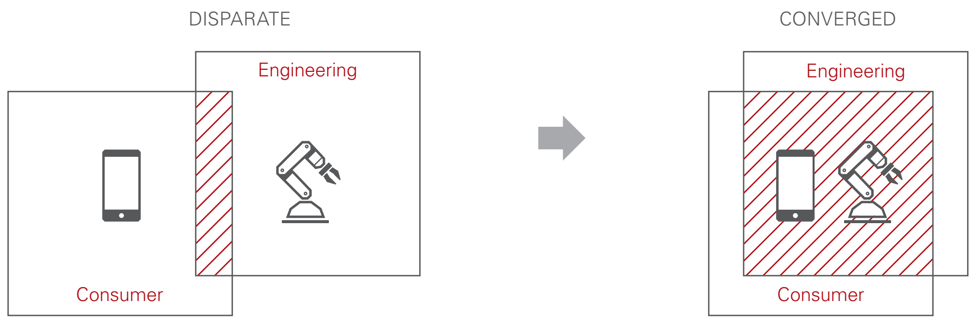
The Evolution of Demands on Engineering Software

Engineering software users of the past typically graduated from a university with an understanding of one programming language. Some were even experienced users who demanded exposure to the darkest corners of programming, with custom memory calls, from-scratch multithreading commands, and hand-optimized performance demands. Software was

"The same concepts that are driving the Maker Movement have rejuvenated engineering. Rather than working with complex protocols that only engineers can understand, today's software must provide an interface that's approachable and understandable to non-engineers on a conceptual level."

—**Bob O'Donnell**, TECHnalysis Research Chief Analyst

THE CONVERGENCE OF ENGINEERING SOFTWARE AND CONSUMER SOFTWARE



hard and unapproachable to those who dared to enter without proper training and previous exposure.

And just like that, things started to change. First, graduating engineers were required to have a broad skillset of programming languages to tackle the challenges handed to them in the workplace. Like a trained warrior switching from sword to axe to bow, today's engineer can jump in and out of Python, C#, HTML, JavaScript, LabVIEW, and Swift. This puts an unprecedented demand on approachability and removes the expectation of expertise. Today's engineer expects to use multiple tools for any given application.

Secondly, the cost of accessing and acquiring data has rapidly decreased while the need for data has risen. And as technology has become more connected, the cost of processors has declined. According to DataBeans, the price of a processor decreased over 30 percent between 2011 and 2015. This has accelerated the need for highly approachable software by introducing more "nontraditional" programmers to the worlds of robotics, home automation, and even general data acquisition and analysis. Likewise, cultural trends like the Maker Movement and the emergence of consumer product start-ups being acquired for unreal amounts of money further illustrate this shift.

An Inevitable Convergence

For engineers, who are defined by the pride of conquering complex challenges, this confluence of usability and technical sophistication couldn't come at a better time. No longer tethered and bogged down by the intricate details of multiple languages, tools, and approaches (like writing an actor framework), they can now refocus on engineering's most grand and impactful challenges (like 5G research and the IoT). In this new tightly integrated future, engineers can find better, faster ways from point A to point B instead of spending their time making better maps.

Likewise, this convergence means that engineers can embrace a future in which they aren't sole proprietors of innovation. With software that is (gasp) easy to use, the rest of the world is catching up. And by acknowledging the prevalence of simplicity and beauty in software of all stripes, more and more smart people will play meaningful roles in major problem solving.

There's no denying that our world is getting more complicated and that our challenges are becoming harder to solve. Being asked to do more with less money, fewer people, and less time only heightens the tension. The sooner we embrace the convergence of engineering software and consumer software, the sooner we'll realize that "simple" is the best way to solve "complex."

US Corporate Headquarters
11500 N Mopac Expwy, Austin, TX 78759-3504
T: 512 683 0100 F: 512 683 9300 info@ni.com

ni.com/global–International Branch Offices
ni.com/trend-watch