Mobile Broadband Connected Future: From Billions of People to Billions of Things

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TABLE OF CONTENTS

Preface

This Yankee Group publication was commissioned by 4G Americas (www.4gamericas.org). All historical and forecast cost and pricing data used in this whitepaper is from Yankee Group research conducted independent of this publication.

The purpose of this report is to discuss the opportunity for wirelessly connected devices. We explore two main themes: Why embed devices for mobile connectivity? And why choose to embed the 3rd Generation Partnership Project (3GPP) family of wireless technologies? The findings of this report impact mobile operators, mobile infrastructure providers, chipset manufacturers, device original equipment manufacturers (OEMs), solution providers, vertical enterprise industries, horizontal consumer and enterprise industries, and other industry ecosystem participants in the future connected world.

Pervasive Connectivity Will Reshape Communications

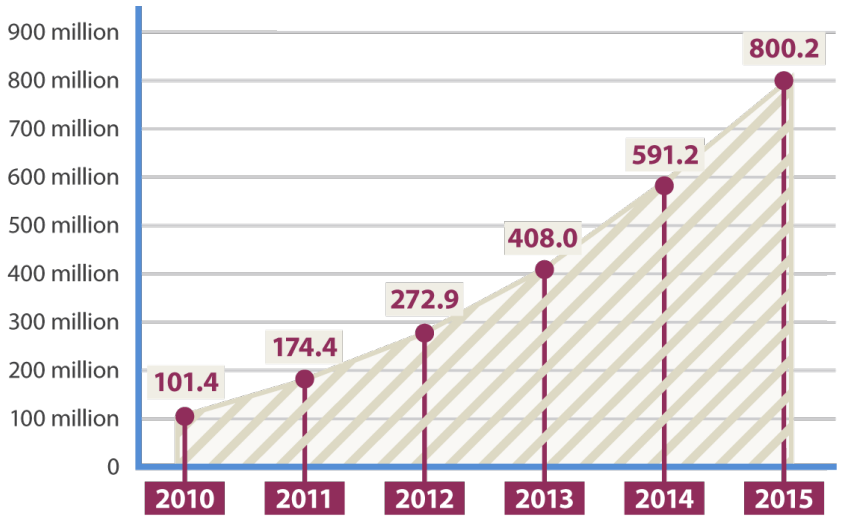
With more than 5.75 billion mobile devices in service across the globe—including 5.2 billion Global System for Mobile Communications-Long Term Evolution (GSM-LTE) devices[1]—mobile telephony is the most dominant form of communications on the planet. Mobile devices are stoking a dramatic and unprecedented transformation in personal communications and Internet access. And wireless technology is expanding the concept of mobility and connectivity beyond the traditional phone. The opportunity for operators and their vendor partners is not just in increasing voice and data subscribers, but also in connecting every facet of a person's technology world. Someday, the industry will look back at terms such as voice and data ARPU as legacy analytics as they consider new research terms more relevant for the all-consuming, growing connected world.

Emerging wireless networking technologies—and the ability to embed connectivity to these networks in virtually all types of devices—are creating a new connected future. While the growth of Internet connectivity globally has been well documented, it was actually constrained by fixed broadband connectivity and a PC-centric worldview. That changed with the introduction of smartphones and 3G connectivity. But unleashing the true power of the Internet actually involved moving beyond even smartphones. The tremendous expansion and evolution of wireless networks combined with growing end-user demand for ubiquitous voice and data access has helped set the foundation for a new generation of smart mobile devices, and we're just beginning to see the potential. Yankee Group predicts that a new segment of connected devices, including

1 4G Americas, July 2011

enterprise machine-to-machine (M2M) connections, tablets and e-readers, will grow to more than 800 million units by 2015 (see Exhibit 1). But there is even greater potential beyond just these existing connected device segments. Some industry players, such as Ericsson and Intel, predict the connected device segment will reach 20-50 billion connections by 2020. If this seems optimistic, consider that Facebook had only 12 million users five years ago and today it boasts 750 million. Pervasive connectivity, just like the social media phenomenon, will happen. It has already begun by combining user demand, network evolution and an ecosystem that is breaking down barriers.

Exhibit 1: Total Global Cellular Connected Devices, 2010-2015
Source: Yankee Group, 2011



Connected Devices Will Proliferate

Yankee Group defines connected devices as solutions that bundle together devices, network services and applications to create, extract, act on or consume information. The world of connected devices is broad and spans handsets, e-readers, connected digital signs, smart meters and fleet tracking devices. To help simplify this ecosystem, Yankee Group sorts connected devices into three groups: enterprise M2M devices, consumer M2M devices and connected computing devices.

- **Enterprise M2M devices service specific business needs.** Enterprise M2M devices include fleet telematics devices, digital signs and smart grid terminals. Like consumer M2M devices, these devices have minimal processing and throughput requirements. Unlike consumer M2M devices, these devices are designed with minimal human interaction in mind, and they address specific business processes to save enterprises money, labor or both.
- **Consumer M2M devices are purpose-built and depend on the cloud.** This category includes consumer tracking and navigation devices, e-readers and mHealth devices that run applications for consumers. These devices have considerably lower processing requirements than computing devices and don't demand high data rates.
- **Connected computing devices are built around multimedia.** This category includes computing devices such as tablets, laptops and smartphones that help consumers browse the Web, listen to music and watch video. These devices have large processing requirements and demand broadband network access.

Connected devices across all three categories will continue to proliferate, driven by accelerating evolution of next-generation wireless networks, advances in wireless modules and a rapidly expanding ecosystem of solution providers. The underlying foundation for these advances is network technology evolution, such as the 3GPP family of technologies, which includes GSM, Enhanced Data rates for GSM Evolution (EDGE), High Speed Packet Access (HSPA), HSPA+ and LTE/LTE-Advanced.

3GPP and the Connected Future

Connectivity has transformed the way consumers and enterprises interact with their devices and assets. The following trends have led industry players and end-users across the value chain toward embedded connectivity:

- Consumers demand a compelling customer experience.
- Consumers demand connectivity at all times.
- Device manufacturers can target new segments of the consumer population.
- Network providers can monetize new services.
- Businesses can gain a competitive advantage over their peers.

Connected device deployments enjoy clear benefits from the use of 3GPP technologies. From the individual device level through to the network infrastructure, 3GPP family networks provide a robust backbone to any device solution. They:

- **Enable global connected device deployments.** 4G Americas estimates that more than 800 operators around the globe have chosen to use 3GPP networks, creating 5.2 billion connections (90 percent of the global cellular market).
- **Are cost-effective.** The pervasiveness of 3GPP networks enables module manufacturers to scale their production across large volumes.
- **Offer M2M solution providers the most flexible range of high- and low-bandwidth network options** ranging from GSM-General Packet Radio Service (GPRS) to LTE:
    - **HSPA and HSPA+ provide mobile broadband service.** The 3GPP family of technologies provides M2M solution providers with global mobile broadband coverage. More than 400 networks in 152 countries provide service using HSPA and HSPA+ technologies[2], and HSPA will remain the leading mobile broadband technology for the next decade.
    - **LTE/LTE-Advanced provides the next frontier for M2M services.** Higher-bandwidth applications in the fleet management, security and digital signage verticals will benefit from the even lower latency offered by LTE. More than 50 commercial LTE networks are anticipated by the end of 2011, 25 of which were launched at mid-year, and there were commercial announcements for future LTE services by 166 network operators at mid-year 2011.[3]

2 4G Americas, July 2011, http://4gamericas.org/index.cfm?fuseaction=page&pageid=939
3 Ibid.

Real-World Applications Flourish

While network evolution provides the foundation for connectivity, connected devices will only be as good as the applications and services built on top of them. However, solution providers, enterprises, and consumer electronics and other device manufacturers are already beginning to demonstrate a variety of connected device solutions across multiple sectors. Several verticals have already taken advantage of connected devices to cut costs and increase efficiency. Fleet management and remote asset monitoring devices have been in use for over a decade. Others, like mHealth devices, smart meters and digital signs, have just begun to ramp up deployments thanks to next-generation HSPA+ and LTE networks.

On the consumer side, new mobile devices are creating opportunities to make classrooms and automobiles more fun and efficient. Examples include:

- **Schools are experimenting with tablets and e-readers.** Thanks to e-readers such as the Amazon Kindle and tablets such as the Kineo, schools are beginning to trial connected device deployments to cut costs and help keep students engaged. A 2010 pilot program at Notre Dame found that students did more than 90 percent of their course reading on their tablets and 70 percent of students found they "never" or "almost never" printed documents.
- **MHealth devices keep consumers in shape.** The U.S. spent $2.5 trillion on health care in 2009. Each year, spending increases between 3 and 4 percent. MHealth devices such as connected scales, wearable heart monitors and remote patient monitoring sensors help doctors better serve their patients and cut costs.
- **Fleet management applications continue stellar growth.** Although fleet management devices have been in the field for over a decade, their future looks even brighter. Yankee Group expects U.S. fleet management connections to grow from about 3.6 million today to 7.5 million by 2015, a compound annual growth rate (CAGR) of 16 percent. Major OEMs including Caterpillar, Komatsu and Volvo Construction will drive the next wave of growth as they embed modules to better repair and maintain equipment.

In this report, Yankee Group further explores the tremendous opportunity for connected devices. The report contrasts different types of connected devices and outlines the benefits consumers and enterprises can realize through wireless enablement. It also examines why the 3GPP family of technologies provides a solid foundation for connected device growth and allows enterprises and solution providers to scale deployments. Additionally, Yankee Group outlines how advances in security, life cycle management and network evolution will overcome common barriers to deploying M2M solutions. Finally, Yankee Group provides real-world examples of how connected device solutions are emerging—and succeeding—across many different vertical sectors.

Connected Devices and Solutions

Yankee Group defines connected devices as solutions that bundle together devices, network services and applications to create, extract, act on or consume information. The universe of connected devices encompasses enterprise M2M solutions, consumer M2M solutions and connected computing devices. These three types of connected devices each have unique form factors, network requirements and applications. Exhibit 2 details the distinguishing characteristics of each type of connected device.

Exhibit 2: The World of Connected Devices
Source: Yankee Group, 2011

	Enterprise M2M	Consumer M2M	Computing Devices
Applications and Content	Enterprise applications Process-specific Machine interaction	Consumer applications Single-application Human interaction	Computing-oriented Rich multimedia Human interaction
Device Hardware	Thin clients Significant processing in the cloud	Thin clients Processor light or processing in the cloud	Thick clients Processor-heavy
Network Connectivity	Narrowband - broadband Batch to real-time	Narrowband - broadband Batch to real-time	Broadband Real-time
Examples	Fleet telematics Digital signage Smart grid	E-readers Tracking devices mHealth	Tablets Smartphones Laptops/netbooks

Yankee Group uses three variables to help profile connected devices:

M2M devices run process-specific applications.

Manufacturers build connected computing devices with multi-taskers in mind. Consumers use their tablets and PCs to browse the Web, listen to music and watch video. Enterprises deploy smartphones to enable employees to make voice calls, access enterprise applications and check e-mail on the go.

M2M devices don't offer the same full-fledged multimedia experience. OEMs design enterprise M2M devices to service specific business needs. Smart meters collect data on energy usage in consumers' homes and provide critical operational insight to utilities. Fleet management devices monitor cargo as it travels from distribution centers to retail outlets. Connected vending machines monitor stock-outs. Moreover, enterprise M2M devices are designed with minimal human interaction in mind. For instance, smart meters often stay in the field for over 10 years before requiring service or maintenance.

Some M2M devices do make their way into consumers' hands. Like their enterprise counterparts, consumer M2M devices serve specific needs. MHealth sensors collect data on a patient's vital signs, tracking devices send data on a subject's location and e-readers deliver text-based content to consumers. However, as e-paper technology improves, the line between e-readers and tablets will blur. Because devices such as the Nook Color deliver rich multimedia to consumers, Yankee Group places them in its connected computing device category.

Consumer devices are more hardware-driven.

To help differentiate their products in a crowded marketplace, connected consumer device manufacturers have packed their products with the latest hardware. At this year's Consumer Electronics Show (CES), Intel and nVidia showcased smartphones running on dual-core processors. Not to be outdone, Qualcomm demoed quad-core processors for tablets and other mobile devices at Mobile World Congress (MWC) 2011. Earlier this year, HTC and LG introduced mobile devices sporting auto-stereoscopic 3D displays. Moreover, Qualcomm is pushing development of augmented reality (AR) gaming to increase demand for more powerful application processors.

Both enterprise and consumer M2M devices eschew the intensive hardware of computing devices. In fact, many M2M devices leverage the cloud to handle computational tasks. For instance, connected vending machines and fleet telematics solutions gather and transmit information about their environment to back-end systems. Those back-end systems depend on cloud servers to process and interpret that information. Consumer M2M devices have adopted a similar model. E-readers designed to deliver e-books to consumers don't need to run the same complex gaming applications as tablets. As a result, e-readers depend on lower-end processors.

Computing devices rely more heavily on mobile broadband.

Consumers use connected computing devices to play online games and stream music or video content. In fact, every device in Yankee Group's connected computing bucket comes with high-bandwidth requirements. Consumer data usage on smartphones provides an illustration. According to data collected from Yankee Group's Mobile Adoption Panel, the average smartphone consumes more than 12.1 MB of cellular data each day. Moreover, consumers running streaming video applications on their smartphones transmit roughly 5 MB of data each minute. Consumers also display sensitivity to latency issues, and multimedia applications must deliver packets in real time to keep consumers happy.

Most consumer M2M devices place far less strain on cellular networks. For instance, e-readers will only transmit 300 KB of data for every e-book download. And both tracking devices and mHealth monitors only transmit kilobytes of location or vital sign information. Most enterprise M2M devices have similar data requirements. Fleet management applications transfer kilobytes of location and cargo information, and connected vending machines send minimal data on stock-outs. What's more, enterprise M2M deployments do not necessarily demand real-time network connectivity: Batch transmissions suffice for many remote-monitoring applications. Although enterprise M2M applications will demand greater data throughput in the future, their throughput requirements will never match those of computing devices.

Why Mobility—and Why 3GPP?

Connectivity has transformed the way consumers and enterprises interact with their devices and their assets. The following trends are leading industry players and end-users across the value chain toward embedded connectivity:

- **Consumers demand a compelling customer experience.** Manufacturers are increasingly adopting a model that takes the complexity of operating a device away from consumers and into software. Five years ago, digital photo frames struggled to take off. To shuffle pictures onto a frame, consumers needed a USB stick, a computer and a lot of patience. Even frames with embedded Wi-Fi still required consumers to configure their home networks. Today, embedded wide-area network (WAN) chips allow manufacturers to ship their devices "hot," or preconfigured to work right out of the box. The success of Vizit and Kodak connected frames is proof enough that consumers have responded.

- **Consumers demand connectivity at all times.** In its 2011 US Consumer Survey, Yankee Group asks respondents to evaluate a range of connectivity attitudes on a scale of 1 to 10. More than 88 percent place a high value on fast Internet speeds. Sixty-nine percent say they need to be connected at all times. And 63 percent say their mobile devices are highly important to their social lives. Consumers are adamant: They need connectivity wherever they go.
- **Device manufacturers can target new segments of the consumer population.** Before WAN connectivity hit digital photo frames, manufacturers focused on youthful demographics when selling the device. By simplifying the experience of setting up a digital frame, manufacturers are now branching out. According to Yankee Group's consumer survey, over 19 percent of consumers in the 65+ age demographic now have a digital photo frame in their household. More than 40 percent of those consumers indicate embedded connectivity was crucial to their purchase decision.
- **Network providers can monetize new services.** In 2010, U.S. carriers saw their data revenue grow by roughly 23 percent. However, during the same period, mobile data traffic grew by more than 132 percent. As data traffic makes operators' traditional device sales less profitable, operators are looking to new segments of the market. Although M2M devices provide low ARPUs compared to handsets, they offer high margins and a new path to profits. AT&T signaled its commitment to connected devices by bringing consumer M2M devices such as e-readers to all its U.S. outlets. T-Mobile has also experimented in the connected device space, launching its own branded cellular photo frame in 2009.
- **Businesses can gain a competitive advantage over their peers.** Connected products and business assets provide visibility into business processes and can create tremendous cost savings. Even enterprises with substantial initial M2M deployment costs can realize a quick ROI as they minimize unnecessary expenditures and maximize productivity within their businesses.
- **Cellular connectivity supports other wireless data standards.** OEMs looking for an alternative to cellular have explored Zigbee, Wi-Fi, Bluetooth and radio frequency (RF) mesh data standards. Compared to cellular, each of these technologies boasts inexpensive chipsets and reduced power consumption. What's more, OEMs have already tested these standards across a range of use cases. Despite their benefits, these standards remain constrained by their short range and limited throughput. As enterprises and OEMs work to deliver truly mobile applications to end-users, these short-range standards will increasingly depend on wireless hubs powered by cellular technology.

When connecting their devices, solution providers need to consider their network technology options. The 3GPP family of technologies has attracted attention from solution providers and consumer device manufacturers for three major reasons:

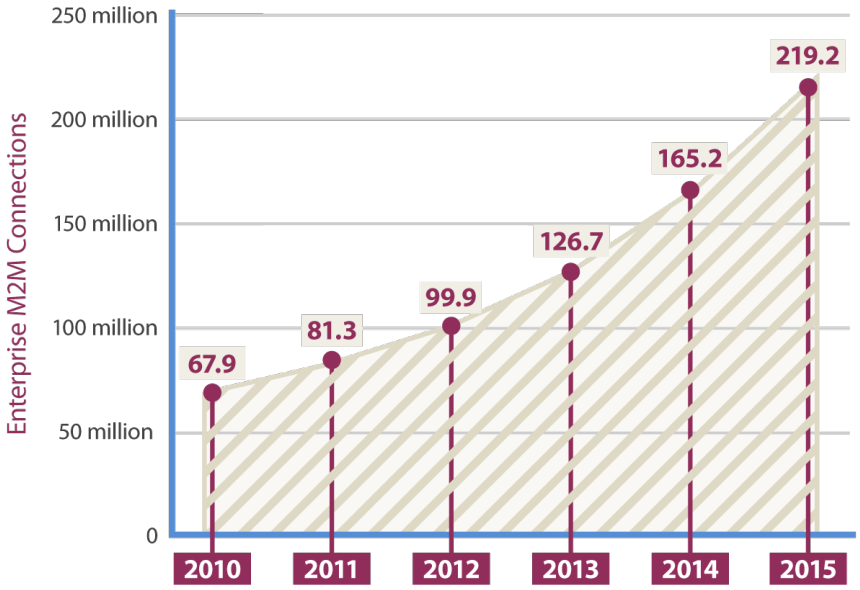
- **The 3GPP family enables global connected device deployments.** GSM, EDGE, HSPA, HSPA+ and now LTE technologies have become de facto global standards for mobile communications. With more than 5.2 billion connections in the world, M2M end-users looking to connect any devices that cross borders will find 3GPP technology to be a more scalable option. For example, in North America, AT&T, T-Mobile and Rogers Canada all place special emphasis on their international M2M offerings and are expanding into growing areas including container monitoring, international fleet management and remote health care.
- **3GPP modules are cost-effective.** The pervasiveness of GSM networks allows 3GPP module manufacturers to scale their production across large volumes. Previous Yankee Group studies independent of this whitepaper estimate that GSM/GPRS chipsets retail for 10-20 percent less than comparable Code Division Multiple Access (CDMA) chipsets. In addition, global module manufacturers have revved up hardware production, driving down costs even further. Many connected device solutions involve large volumes of modules, and even small hardware price advantages can add up to a significantly decreased total cost of ownership (TCO) across a deployment.
- **The 3GPP family of technologies offers solution providers the most flexible range of high- and low-bandwidth network options:**
    - **HSPA and HSPA+ have become the most widely deployed mobile broadband standards.** The 3GPP family of technologies also gives solution providers global mobile broadband coverage. More than 400 networks in 152 countries provide service using HSPA and HSPA+ technologies. For example, recent HSPA+ network upgrades have helped T-Mobile USA provide peak downlink throughput of up to 42 Mbps for high-bandwidth applications. HSPA+ also provides high-speed data coverage fallback in regions without LTE service.

- **LTE/LTE-Advanced has become the leading next-generation wireless technology.** Every M2M application has unique bandwidth and latency needs. Bursty SMS apps can fare well on a GSM/GPRS network. But higher-bandwidth applications in the fleet management, security and digital signage verticals will benefit from the low latency offered by LTE. Moreover, GSM module manufacturers including Cinterion and Telit continue to produce Universal Mobile Telecommunications System (UMTS) and HSPA+ modules that ensure backward-compatibility with earlier 3GPP standards. This greatly enhances reliability for mission-critical M2M deployments.

The Role of Embedded Modules in Business Solutions

While connected consumer devices attract more media attention than connected enterprise devices, the role of connectivity in enterprise applications should not be discounted. Although many connected enterprise applications have been around for the better part of the decade, real growth in the area is accelerating in 2011 and will continue to swell through 2015. Yankee Group anticipates U.S. cellular M2M connections for enterprise purposes to nearly triple from their 2011 levels of 81.3 million to 219.2 million in 2015, a CAGR of almost 23 percent (see Exhibit 3).

Exhibit 3: Global Cellular M2M Enterprise Connections, 2010-2015
Source: Yankee Group, 2011



Connected enterprise devices are quietly augmenting—and in many cases reshaping—the way enterprises do business by creating greater visibility, transparency, efficiency and accountability in multiple layers of the enterprise, including the following five key functions:

- **Decreasing fuel costs.** Location-based M2M applications help enterprises optimize vehicle routes and delivery schedules to significantly reduce fuel consumption in a period when the average cost per gallon of diesel in the U.S. has increased more than 145 percent over the past decade. M2M applications allow enterprises to map efficient routes, maximize truck rolls and eliminate unnecessary trips altogether.

- **Curtailing unnecessary jobs.** Across nearly all verticals, M2M applications help enterprises automate menial tasks and empower the allocation of human capital toward higher revenue-generating activities. In the connected energy sector, for example, automated meter infrastructure (AMI) applications eliminate the need for human meter readers to manually view each meter, saving significant time and fuel costs. In the digital signage space, connected billboards eliminate the time-consuming and dangerous requirements of physically replacing advertisements or driving around during the evening hours simply to determine whether or not display lights are functioning.
- **Revolutionizing customer service models.** Connected assets arm service and maintenance departments with the technology to create proactive, rather than reactive, service models. Remote monitoring technology allows service organizations to diagnose problems from off site, allowing them to prevent small problems from becoming larger and more costly and ensuring that if a technician or repairman does need to be dispatched, he or she will have a much higher probability of a first-time fix, an important KPI in many service departments. Finally, embedded assets bolster longer-term service-level agreements (SLAs) and guaranteed uptime contracts, which help enterprises lock in customers for a substantially longer period of time.
- **Creating visibility into existing business processes.** An industrial enterprise with multiple assets in its deployment gains tremendous business intelligence by connecting its machines. One data stream can support multiple facets of a single organization. For example, an enterprise with an industrial cutting machine can monitor the machine for maintenance purposes, study how it operates to design and engineer new models, and analyze output levels to shift distribution and production to underutilized assets. Although many early M2M solutions created stand-alone data streams accessed through separate portals, more enterprises are integrating the feedback from their connected devices into their legacy customer relationship management (CRM) and enterprise resource planning (ERP) back-end systems.
- **Generating new revenue streams.** While the lion's share of today's M2M applications are designed to improve efficiency and cut costs, the development of embedded wireless connectivity is creating the opportunity for enterprises to leverage newfound mobility to create new sources of revenue. The increased availability of 3G and 4G networks will power digital signage in green-field areas such as taxi cabs and airports. On the retail side, wireless point-of-sale (PoS) systems and kiosks will allow retailers to create mobile storefronts to capitalize on sporting events, seasonal trends and outdoor venues. Enhanced track-and-trace systems will allow subprime lenders to relax credit standards when renting assets to consumers, giving them confidence that they will be able to retrieve their items in the event of default.

Embedded devices profoundly impact the enterprises that deploy M2M solutions, and many enterprises leverage the benefits gained through connectivity into competitive advantages over industry peers. M2M solutions in the enterprise have progressed from being pet projects developed by highly fragmented groups within a company to robust, well-structured deployments that touch all facets of an organization and generate business intelligence integral to core business processes.

Building an enterprise M2M solution or successfully supporting a connected consumer device requires a concerted effort from operators, hardware vendors and platform/service providers for deployment and secure management. Despite the fact that there is widespread consolidation and collaboration in the M2M ecosystem, the M2M value chain remains extremely complex, and the idea of a true end-to-end enabler is not presently viable.

Widespread proliferation of M2M and connected devices will depend on cooperation between numerous industry players, and the establishment of common standards will help define the relationships between different solutions. Organizations like the Open Mobile Alliance (OMA), the GSMA, the European Telecommunications Standardization Institute (ETSI) and the Alliance for Telecommunications Industry Solutions (ATIS) must continue their work to define the M2M ecosystem and basic requirements, standardize back-end system access, and determine how different value chain members can pool their strengths in building and promoting the M2M industry.

3GPP Mobile Networks

Building the mobile broadband connected future depends on highly standardized interfaces enabling ubiquitous connectivity between devices and access networks. The 3GPP produces these standards for a family of radio access technologies that began with the second-generation GSM, originally an ETSI project aimed at harmonizing mobile cellular communications across the European Union. Today, 3GPP expands on ETSI's regional scope to maintain and evolve mobility standards for second-, third- and fourth-generation communications systems operated by more than 800 network operators around the globe. These 3GPP standards supply equipment vendors, terminal device suppliers and mobile network operators with comprehensive interface specifications that, much like standard rail gauges did in the early days of the railroads, ensure global consistency.

3GPP Family of Technologies

Today, the 3GPP family of technologies provides a road map for wireless operators, device OEMs and solution providers that begins with 2G as its foundation (including GSM/GPRS/EDGE) and extends to 3G and beyond (including UMTS-HSPA and LTE/LTE-Advanced). The global support for these technology standards is already impressive and growing:

- **GSM/GPRS/EDGE:** GSM is the most widely deployed cellular technology in the world and provides voice and data service via GPRS/EDGE. Most GSM networks today support EDGE, representing more than 545 networks in approximately 198 countries.[4]
- **UMTS-HSPA:** UMTS-HSPA has established itself globally. Nearly all UMTS-HSPA handsets are also GSM handsets, so UMTS-HSPA users can access the wide base of GSM networks and services. There are more than 752 million UMTS-HSPA customers worldwide[5] spanning more than 400 commercial networks.[6] Almost all UMTS operators are deploying HSPA for two reasons: First, the incremental cost of HSPA is relatively low; second, HSPA makes such efficient use of spectrum for data that it results in a much lower overall cost per megabyte of data delivered. Already, there are more than 3,000 commercial HSPA devices available worldwide from 262 suppliers.[7] Devices include handsets, data cards, modems, routers, laptops, media players and cameras.
- **UMTS-HSPA+:** Operators have begun deploying evolved HSPA features. As of July 2011, 143 HSPA+ networks were in service in 74 countries.[8] As the technology matures, upgrading to HSPA+ will likely represent a minimal investment for operators to significantly boost network performance.
- **LTE:** LTE has become the technology platform of choice as GSM-UMTS and CDMA/One Carrier Evolved, Data Optimized (EV-DO) operators are making strategic, long-term decisions on their next-generation platforms. Twenty-five LTE networks were deployed across 17 countries as of mid-year 2011, with a total of 50 commercial LTE launches expected before year-end 2011.[9]
- **LTE-Advanced:** LTE-Advanced (Release 10) is a natural evolution of initial LTE that meets all International Mobile Telecommunications (IMT)-Advanced requirements. Carrier aggregation (CA), advanced Multiple Input/Multiple Output (MIMO) techniques, enhancements for heterogeneous networks and coordinated multipoint are just some of the features defined in Release 10 and beyond that are generally associated with LTE-Advanced. Several operators, including NTT DoCoMo, SK Telecom and Clearwire, have announced their expected commercial launch of LTE-Advanced in 2013.

Exhibit 4 on the next page summarizes the various 3GPP technology types described above, including network characteristics, typical user downlink and uplink speeds, and global deployment status.

4 GSA: The Global Mobile Suppliers Association [April 2011]
5 Informa Telecoms & Media, WCIS
6 4G Americas
7 GSA: The Global Mobile Suppliers Association [April 2011]
8 4G Americas
9 Ibid.

Exhibit 4: 3GPP Family of Technologies
Source: Rysavy Research, Mobile Broadband Explosion, September 2011 and 4G Americas, July 2011

Technology Name	Type	Characteristics	Typical Downlink Speed	Typical Uplink Speed	Network Deployments (as of July 2011)
GSM	TDMA	Most widely deployed cellular technology in the world. Provides voice and data service via GPRS/EDGE.	16 to 85 Kbps	8 to 85 Kbps	More than 800 in 219 countries
EDGE	TDMA	Data service for GSM networks. An enhancement to original GSM data service called GPRS.	70 to 135 Kbps	70 to 135 Kbps	More than 545 in 198 countries
HSPA*	CDMA	Data service for UMTS networks. An enhancement to original UMTS data service.	1 to 4 Mbps	500 Kbps to 2 Mbps	More than 400 in 157 countries
HSPA+	CDMA	Evolution of HSPA in various stages to increase throughput and capacity and to lower latency.	1.9 to 8.8 Mbps (in 5/5 MHz)	1 to 4 Mbps (in 5/5 MHz)	143 in 74 countries
LTE	OFDMA	New radio interface that can use wide radio channels and deliver extremely high throughput rates. All communications handled in IP domain.	6.5 to 26.3 Mbps in 10/10 MHz	6 to 13 Mbps in 10/10 MHz	25 in 17 countries

*HSPA and HSPA+ throughput rates are for a 5 + 5 MHz deployment

3GPP Technologies and Connected Devices

Regardless of generation, 3GPP network technologies have enabled M2M communications. Ranging from simple leveraging of short message service (SMS) text messages in GSM networks to quality-of-service (QoS)-sensitive video streams available from modern LTE networks, 3GPP networks naturally accommodate the wide range of non-human communications requirements. By addressing requirements for high speed, high capacity, low latency and strong management capabilities, the 3GPP family of technologies serves as an ideal foundation for developing a future-proof road map for connected devices.

The set of 3GPP technologies provides various options for connected device solutions, depending on cost, bandwidth, latency or coverage requirements. Exhibit 5 on the next page displays the throughput, latency and sample use cases of 3GPP technologies for connected device deployments.

Each of these technology characteristics impacts connected device solutions in several ways:

- **Throughput.** An adequate level of throughput is crucial to providing more overhead bandwidth to data-intensive video streaming use cases as well as more complicated enterprise M2M processes, as enterprises layer multiple applications onto a single device connection.
- **Latency.** For high-quality video streaming applications, low latency plays a critical role in reducing pixelation and providing a superior picture. This would be crucial for supporting imagery for consumer connected devices including tablets and connected cars, as well as mHealth and digital signage use cases.

Exhibit 5: 3GPP Technologies Impact on Connected Device Solutions
Source: Rysavy Research, Mobile Broadband Explosion, September 2011, and Yankee Group, 2011

Technology Name	Typical Downlink Speed	Typical Uplink Speed	Latency (Milliseconds)	Yankee Group Estimate Relative Average Module Pricing (X=100%-LTE Module)	Sample Use Cases
GSM/GPRS	16 to 85 Kbps	8 to 85 Kbps	700 ms	.18X	Parking meters, container tracking
EDGE	70 to 135 Kbps	70 to 135 Kbps	300 to 600 ms	.25X	Consumer and fleet telematics
HSPA*	1 to 4 Mbps	500 Kbps to 2 Mbps	100 to 125 ms	.35X	E-readers, smart meters
HSPA+	1.9 to 8.8 Mbps	1 to 4 Mbps	<50 ms	.75X	Video surveillance, interactive kiosk
LTE	6.5 to 26.3 Mbps in 10/10 MHz	6 to 13 Mbps in 10/10 MHz	10 ms	X	Video surveillance, doctor/patient consultations, digital signage, tablets

*HSPA and HSPA+ throughput rates are for a 5 + 5 MHz deployment

- **Module pricing.** Historically, module prices have decreased over time as hardware manufacturers achieve greater volume, and Yankee Group expects this trend to continue with new emerging technologies. While containing hardware costs is an important component of managing deployment expenditure, enterprises must also choose a technology that can accommodate the maturation or expansion of a deployment's original use case.

Connected Device Networks for Today and Tomorrow

Connected device applications are no stranger to 3GPP-based mobile networks, as they have used 3GPP family technologies for over a decade. Ranging from simple SMS-based applications that control billboards to more sophisticated transaction terminals deployed with GPRS, GSM networks have successfully hosted a number of M2M applications.

As 3G-enabled devices become the norm for handset users, mobile network operators will shift radio capacity to ensure high-quality support for 3G voice calls and Internet data access. Ultimately, mobile network operators will need to reduce radio resources reserved for GSM network access. Although 2G access will never completely disappear, future 2G access may become limited in some geographies and some operators will re-farm 2G spectrum for 3G and 4G networks. M2M device innovators must produce solutions capable of operating in 3G spectrum bands to ensure consistent access to mobile networks as more traffic moves to 3G and 4G mobile broadband networks.

But this change brings benefits as well. Support for Internet Protocol (IP) data traffic in UMTS and LTE networks is tightly integrated into the radio air interface and the core network. Each successive generation of radio technology yields improvements in IP data transmission across mobile radio networks. M2M device innovators can now take advantage of these advancements to introduce new application functionality to drive value and expand market reach.

3GPP and Standards Development

Much of the technical success enjoyed by 3GPP network technologies is the result of a vigorous, transparent and disciplined consensus standards process. Technical contributions from mobile operators, equipment suppliers and terminal vendors flow into the 3GPP process for consideration. Under supervision of elected volunteer leadership drawn from this diverse community, an appropriate Technical Specification Group (TSG) evaluates the merits of contributions and folds accepted technical approaches into draft Technical Specifications. The benefits of this approach include:

- **Comprehensive systems-oriented standards design.** With a disciplined process for considering requirements and architectural solutions, 3GPP continues to evolve mobile communications technology with a systems approach. By taking this structured methodology, 3GPP ensures it fully addresses future needs while respecting needs of established deployments.
- **Technical rigor.** The 3GPP review process exposes ideas to scrutiny from a global community of engineering experts across a wide range of disciplines including radio access, IP networking and communications security. With rigorous analysis and vigorous debate, 3GPP methodically vets proposals to ensure high quality and compatibility.
- **Solid documentation.** The global nature of the 3GPP process means that specifications must be clear and complete. With many vendors and network operators coming from regions where English is not the primary spoken language, 3GPP must ensure that its documentation is free of muddled text and colloquial usage. The amazing variety of devices available today from innovators around the world speaks to the high quality of 3GPP output technical specifications.
- **A vibrant, market-driven evolutionary path.** Even as LTE's Orthogonal Frequency-Division Multiplexing (OFDM) air interface nears the limits of what can be achieved for radio spectrum efficiency, more opportunities exist to improve signaling, gain efficiencies in the core network and expand terminal device scale. The 3GPP contribution-driver process draws from subject matter experts representing device innovators, network builders and mobile operators. The breadth of contribution activity from an active community ensures a living standard that continues to evolve in a disciplined progression.

Specification for Machine Type Communication

Designed for high-scale deployment, 3GPP radio and core network architectures have succeeded in supporting billions of connections around the globe. Even with this success, 3GPP continues evolving its network architecture to drive additional efficiencies into mobile networks. In particular, work efforts for future releases of 3GPP standards address further scale requirements anticipated for embedded devices, specifically work referred to as "machine type communication" (MTC), 3GPP's terminology for M2M, person-to-machine and machine-to-person communications. These requirements build on the inherent data networking capabilities supplied by 3G and 4G architectures to simplify device design, reduce power consumption, increase network efficiency and simplify operations.

Because MTC requirements vary from application to application, 3GPP identifies a set of important characteristics helpful in categorizing application MTC features in its Technical Specification (TS) 22.368 (see sidebar at right).

MTC FEATURES

- Low Mobility
- Time Controlled
- Time Tolerant
- Packet Switched (PS) Only
- Small Data Transmissions
- Mobile Originated Only
- Infrequent Mobile Terminated
- MTC Monitoring
- Priority Alarm
- Secure Connection
- Location-Specific Trigger
- Network Provided Destination for Uplink Data
- Infrequent Transmission

In addition to providing feature categories, TS 22.368 supplies a set of service requirements including:

- **General requirements** to link a subscription with specific MTC features, network behaviors in the face of bursty data and signaling traffic, efficient registration with the IP multimedia core network subsystem, power consumption mechanisms, etc.
- **MTC device-triggering mechanisms** to govern server-initiated triggers, restricting triggers to authorized servers, trigger failure indications, etc.
- **Addressing facilities** to enable public IPv6 and IPv4 addresses as well as private IPv4 address space support.
- **MTC subscriber identifiers** structured to scale two orders of magnitude higher than for human-to-human communications.
- **Efficient MTC charging support** that reduces call detail record generation while ensuring sufficient data is available to account for network utilization.
- **Security considerations** to ensure the design does not degrade the integrity of the network.
- **Use of existing management interfaces** for control of MTC devices.

Beyond these requirements, each MTC feature shown in the sidebar on the previous page has specific requirements. For example, the time-tolerant feature requires the architecture provide operators with mechanisms to govern access to the network and the architecture specify what should happen if the device is not reachable.

There has been no shortage of mobile wireless networking standards jockeying for prominence since the early days of cellular radio. CDMA, time-division multiple access (TDMA), time-division synchronous code-division multiple access (TD-SCDMA), integrated digital enhanced network (iDEN) and WiMAX technology standards have each been positioned as important standards, yet none has come close to the success and pervasiveness of the 3GPP family of technology standards. The benefits of this success extend to connected device innovators. As these designers look toward clever devices needed to make future creative applications possible, 3GPP protocols offer the optimal path forward.

Lowering Entry Barriers for Connected Devices and Solutions

Of course, pulling together devices, network services and applications creates complexity for solution providers. In particular, the following barriers need to be addressed by any solution provider considering a connected device project (see Exhibit 6):

- Device selection, standardization and provisioning
- Connectivity, including type, activation and future-proofing
- Data integration, management and visibility
- Scaling across geography, products and customer segments
- Building the business case, both internally and externally

Fortunately, significant progress has been made to address these challenges. The connected device ecosystem has come together for the 3GPP family of technologies to create effective innovation around:

- Provisioning M2M and connected devices
- Life cycle management
- Service platforms for managed connectivity
- Certification and testing
- Security
- Building the business case and controlling TCO

Exhibit 6: Challenges Faced in Building Connected Device Solutions
Source: Yankee Group, 2011

Provisioning M2M and Connected Devices

Both setting up a connected device and monitoring its activity over its entire life span are critical components to any successful M2M solution. Because of the many different M2M applications and connected device use cases, the provisioning process (i.e., establishing a connection to the network and setting up basic connectivity billing systems) can vary widely across different devices. There are a few key components of both consumer and enterprise use cases that set the provisioning process for connected devices apart from more traditional computing devices:

- **Consumers want connected devices to work out of the box.** The newest trend for consumer devices is to ship connected devices such as tablets and e-readers "hot," or already connected. The Kindle was so successful because of its easy setup and lack of a recurring charge for connectivity. Most consumers would rather enjoy the benefits and capabilities of their connected devices rather than actively set up and manage their connections and juggle several bills. Connected consumer device manufacturers that are able to provide out-of-the-box connectivity and, for devices with recurring connectivity fees, intuitive interfaces for monitoring bandwidth consumption and making payments will ultimately be the most successful.
- **Enterprises want a provisioning process that allows them to scale quickly.** As enterprises with more ambitious, large-scale deployment plans investigate the viability of M2M solutions, they recognize the need for a provisioning platform that can allow them to connect large volumes of devices across broad geographies. For these types of processes, the provisioning process must be as standardized as possible to ensure a consistent and smooth rollout. Enterprises often require connections among several types of devices in their deployments, and a provisioning platform must be flexible to accommodate these needs. In previous years, operators shipped deactivated subscriber identity modules (SIMs) to OEMs, which installed the SIMs in devices and then called to have them activated in large batches. This required the OEM to keep track of individual SIM numbers, as well as which devices were actually deployed into the field versus those still in queue in warehouses or being tested at the factory. New provisioning platforms allow companies to ship devices that automatically activate when end-users power them on, as well as to keep track of SIM identifiers and various rate plans in controlled data centers.
- **Network operators want provisioning services that help them maximize revenue.** Compared to handsets with an ARPU near $50 per month, most M2M devices provide modest monthly revenue in the $2-$10 range, according to Yankee Group data. Playing a heavily involved role in facilitating and troubleshooting the provisioning process can eat away at the operator's already narrow M2M margins. Network operators have developed or partnered with specialized M2M provisioning platforms that help automate the provisioning process and manage a multitude of rate plans across different network standards and geographies. Provisioning platforms also help manage time-of-day billing, allowing network operators to shift M2M traffic to off-peak hours and help alleviate the bandwidth crunch on their networks.

Members of the GSM family of connectivity have been active in promoting automatic connectivity with fewer requirements on the end-user for activation. Although 3GPP family operators such as AT&T and T-Mobile and connectivity management companies such as Jasper Wireless all currently support embedded SIMs, the GSMA and working groups within ETSI have begun standardizing embedded SIMs. In 2010, an ETSI working group called the Smart Card Platform (SCP) committee outlined two form factors for universal integrated circuit cards (UICCs) designed to cope with the harsh vibrations, shocks and temperatures often found in industrial environments. In the same year, the GSMA formed a group of operators and SIM vendors to promote the evolution of current SIM provisioning processes. The group reported its findings to ETSI in February 2011, with hopes of seeing standard embedded UICCs deployed in the 2012 time frame.

Because embedded SIMs are being built into the existing structure of devices rather than bolted on, they allow for much more compact and damage-resistant connected device design. The embedded quality aids in the development of consumer devices, where aesthetics and form factors are essential to end-user adoption, as well as in typical enterprise deployments, where use cases often require a greater level of durability than consumer-grade plastic SIMs can provide. Embedded SIMs will also allow greater late-stage personalization and could in some cases empower end-users to switch dedicated operators without installing new hardware.

Life Cycle Management

The differences between handsets and M2M and connected devices don't stop at the provisioning phase. The life span of a typical consumer handset is two to three years, while some M2M devices can be in the field for eight to 15 years. Automotive OEMs promoting new connected cars expect the embedded module to last the lifetime of the vehicle. With narrow margins in the smart metering vertical, just one truck roll to support a field-deployed meter can hurt the ROI for the meter. Time spent in the distribution channel, whether in testing phases, waiting for deployment or sitting idle in inventory, adds to the longevity requirements of M2M and connected devices.

Much can change over the life cycle of a connected device, and M2M solution providers need visibility and access into the device's performance throughout the duration of a deployment. This basic requirement creates demands on hardware manufacturers and M2M solutions providers alike, including the following:

- **Connected device hardware needs to be capable of two-way communications and over-the-air (OTA) updates.** While this may sound like a no-brainer, many enterprises deploying solutions built for a single purpose, such as simple remote monitoring, used cheaper, dumbed-down devices that rendered them inaccessible from remote locations. The purpose and bandwidth requirements of an M2M solution can change several times over the course of a deployment, and hardware manufacturers and solutions providers need to help educate enterprises in creating this flexibility. Two-way communications also allows end-users to update device security settings, load new firmware, switch carriers and download new applications.
- **SIMs need to be able to adapt to different ownership over a device's lifetime.** While traditional consumer devices may not often change hands over the lifetime of a device, the next generation of connected devices will. The average American owns a car for four to five years, while the life span of the typical automobile is somewhere between 10 and 15 years. This means the next generation of connected cars will likely change ownership at least two or three times. To keep service subscription revenue alive for multiple owners, the auto OEM or service owner needs to be able to seamlessly switch end-user ownership and billing of the SIM, and in many cases ensure QoS in a different geography.
- **Solutions need to be future-proofed to allow for different network transitions and availabilities.** Although network transition is largely driven by the handset side of the market, many operators are looking to retire GPRS networks and re-farm spectrum in support of HSPA, HSPA+ and LTE networks. While timelines for sun-setting 2G networks vary per operator geography, many carriers will not guarantee 2G connectivity past 2020, and they are already encouraging enterprises with deployment life cycles of longer than three years to consider 3G or 4G technology. While 3G networks provide excellent coverage in most regions, the premium on hardware in comparison to 2G modules can be a deterrent to price-sensitive organizations. In addition, enterprises may deploy M2M solutions in areas without cellular coverage and will have to incorporate alternative communications technologies into their solutions. As such, enterprises seek hardware solutions that allow them to take advantage of low-cost 2G and 3G technology today and easily transition to more advanced networks in the future, without the need for costly retrofitting or complete hardware replacement.

Service Platforms for Managed Connectivity

While hardware durability and functionality are essential to successful life cycle management, hardware comprises only a piece of an M2M solution. Historically, platform providers have been as specialized as the industries they serve. While there may be myriad M2M solutions and countless process models, most solutions have a common need for platforms to support hardware on a network and manage the data flow between these connected assets and the end-user.

Connectivity platforms often serve both operators and enterprises in providing provisioning and device management capabilities. For operators, third-party platform providers reduce the cost of supporting M2M solutions, as the platform provider can handle most customer service issues and maintain customer access to device management portals. For enterprises, third-party platforms speed time to market by minimizing provisioning time, activating SIMs remotely and scaling globally with a platform used by operators around the world.

Over the past few years, carriers have become increasingly active in developing their own connectivity platform capabilities, either in-house or through acquisitions. While recognizing the differences between connected device and handset consumers, carriers have adopted provisioning programs for smartphones and cell phones, built separate M2M platforms or joined forces with traditional M2M platform providers. For example, in the U.S., Jasper Wireless provides AT&T with a connectivity management platform, T-Mobile utilizes RACO Wireless for the same purpose and Verizon leans on nPhase (its joint venture with Qualcomm) to provide these services.

In Europe, many operators including Vodafone Orange and Telecom Italia are building out connectivity management platforms in-house, while Telefónica and O2 rely on Jasper Wireless' services. Network builders are getting into the connectivity management game as well. Ericsson's acquisition of Telenor Connexion's platform in April 2011 has positioned it to provide connectivity platform services to operators and/or enterprises seeking to build more carrier-agnostic, international solutions. Mobile virtual network operators (MVNOs) are another key source of platform capabilities. Worldwide, MVNOs such as KORE Telematics and Numerex re-sell connectivity from carriers and provide device management services to end-users, who can take advantage of the MVNOs' relationships with multiple carriers. Finally, on a more granular level, innumerable platforms provide connectivity support within specific vertical markets such as fleet management or security.

An operator's decision of whether to build a connectivity platform in-house or outsource the responsibility to a third party hinges on what the operator believes is most profitable in the long run. Operators can gain incremental revenue per connection but take on more customer service responsibility by providing services in-house, or they can outsource the opportunity to a third-party provider, capping revenue opportunity to minimize costs. Regardless of the operator strategy, the telecom industry has clearly recognized the need for connectivity platforms to build out and manage M2M deployments.

Certification and Testing

As the demand for connected devices has risen dramatically over the past few years, standardization and certification bodies have been forced to streamline their processes to enable speedier solution development and decreased time to market. Regulatory structures differ by country, but all areas include some mandatory regulatory certification as well as voluntary certification, with processes carried out by individual operators to ensure the integrity of their networks.

In Europe, M2M module or terminal deployers need to navigate Restriction of Hazardous Substances (RoHS), Waste Electrical and Electronic Equipment (WEEE) and Radio and Telecommunications Terminal Equipment (R&TTE) directives, which ensure the safety of connected devices with regard to the materials used in the manufacturing process as well as the safety of the signals generated. An approved device receives a Conformité Européenne mark and is authorized for deployment. European operators also often employ their own voluntary certification processes to protect their networks against malicious device behavior: With the deployer ultimately liable for any damage caused to the network from his or her connected devices, it is in the interest of both parties to make sure devices operate correctly.

In the U.S., new devices must pass Federal Communications Commission (FCC) scrutiny and attain PTCRB certification for GSM/UMTS deployments. The FCC certification process examines power and voltage use as well as radiation emissions. The PTCRB was established by a group of North American operators in 1997 with the intent of agreeing on a set of device performance requirements and utilizing a third-party testing system to help safeguard member networks against harmful devices. Any device that passes PTCRB testing also receives Cellular Telecommunications Industry Association (CTIA) approval. On top of these requirements, North American operators require their own certification processes. Both AT&T and T-Mobile have significantly reduced the duration of the certification process from several months to weeks by expanding lists of pre-certified modules and building specific device certification and testing centers. T-Mobile requires only FCC/PTCRB approval for M2M devices in an effort to speed time to market for emerging solutions.

Some operators and vendors believe that to reach a connected world vision of billions of connections by the end of this decade, it's important to continue to further streamline certification process industry-wide. An ideal option for industry streamlining could be one set of harmonized modular regulatory requirements that would be acceptable by all regulatory authorities including the FCC and R&TTE, covering all 2G, 3G and 4G frequency bands and coding schemes (GSM, GPRS, EDGE, HSPA and LTE). The potential ambition or objective would be to ensure compliance with regulatory and industry standards on a module level (modular approach) so that when modules are integrated into end products, much additional required testing could be avoided.

Security

Today's smartphones carry a treasure trove of sensitive information. Within minutes, a malware-infested application can dig up transaction data, credit card numbers and health care information. Hackers have already taken notice and in the past year alone security researchers found "Gemini" malware on Android devices, Google removed 50 malware-infected applications from its Android market, and Dutch hackers used a botnet to steal online banking credentials on jail-broken iPhones.

The data sent by M2M devices is just as valuable. Connected automated teller machines (ATMs) transmit sensitive financial information over the network. MHealth applications contain personal health records. Smart grid applications can reveal a household's intimate energy consumption habits or expose utility company data. On the private sector side, as enterprises tie M2M applications to their back-end systems, internal information can be at greater risk of exposure.

Yankee Group identifies four major security threats to M2M deployments:

- **Attackers can physically tamper with an M2M device.** Although consumers keep their smartphones close at hand, M2M devices can remain unmanned for long periods of time. This makes M2M devices particularly vulnerable to theft. In 2010, the Johannesburg Road Agency (JRA) installed 600 traffic lights with M2M modules programmed to alert the JRA office in the event of a malfunctioning light. Within months, thieves stole two-thirds of the SIM cards in these devices, and the city was forced to foot a $1.3 million bill to repair the damage.
- **Devices are vulnerable to protocol attacks.** A denial-of-service (DoS) attack can happen on any WAN-connected device by simply jamming the radio interface. But an overload of bogus authentication can also bring down an M2M deployment.
- **OTA security is a pain point.** Signals traveling over the air will always remain vulnerable to snooping. GSM networks have historically used the A5/1 cipher to encrypt communications as they travel from the device to a carrier's base station. However, researchers have published a number of attacks on A5/1. In 2006, Elad Barkan demonstrated an attack on A5/1 that decrypted mobile phone conversations in real time. Similar attacks can target M2M devices.
- **M2M devices require secure IP communications.** Attackers can also target the link between a carrier's network and a back-end M2M application. The GSMA has not specified a security protocol for IP-based transitions, and Internet traffic can potentially interfere with the secure data streams from M2M devices.

Although M2M deployments both face and pose security risks, the wireless industry has proposed a number of solutions:

- **SIM card security.** SIM card manufacturers have deterred thieves using a number of techniques. On a physical level, device manufacturers have begun soldering the SIM into the device, which prevents easy SIM card removal. They've also married SIM cards to devices using a unique International Mobile Equipment Identity (IMEI). If a thief removes a SIM card from its device, the SIM is rendered unusable. Thirdly, SIM card manufacturers such as Gemalto have made efforts to ensure their M2M SIMs will not support voice, meaning a thief cannot insert a stolen SIM into a handset to make calls. Lastly, M2M solution providers can geo-fence stationary M2M deployments. Should a thief take a SIM card outside its geo-fence, the SIM card will disable itself. Additionally, OEMs have added tamper sensors to their devices that alert carriers to drop compromised devices from their networks.
- **A full transition to the A5/3 protocol.** In light of the security vulnerabilities of the A5/1 cipher, GSM network operators have begun actively transitioning to the A5/3 protocol. Both carriers and manufacturers have already begun to mandate the new standard. For example, AT&T has required A5/3 on its devices since 2010. Device manufacturers have implemented the standard at the chip level. The A5/1 protocol depends on a 64-bit key to decrypt transmissions. The newer A5/3 protocol has a 128-bit key, making it far more secure.
- **IP security maturation.** Many parties in the value chain have stepped in to secure the link between carrier networks and back-end M2M applications. Carriers have done the most work. Partnerships with players including Cinterion have allowed carriers to add an end-to-end security overlay between the M2M device and back-end servers for security sensitive applications like smart grid and mHealth. Furthermore, the transition to IPv6 will take security one step further by enriching support for IPsec, which authenticates and encrypts transmissions at the packet level.

The most vulnerable M2M deployments require strict end-to-end security solutions. Some smart grid providers will encrypt data locally with Transport Layer Security (TLS) encryption using a National Security Agency (NSA)-approved OTA transmission cipher. The cipher is then stacked on top of a custom Access Point Name (APN), which creates a secure Virtual Private Network (VPN) tunnel for data transportation over the Internet. TLS authentication on every device requires proper credentials and certificates and prevents unauthorized grid access.

Less vulnerable or information-sensitive M2M deployments have less stringent security requirements. For example, most fleet management solutions don't involve highly sensitive data (generally speaking, raw vehicle location is uninteresting to potential data attackers). The use of advanced encryption when sending fleet data can lead to higher bandwidth costs, so enterprises only deploy advanced security measures when necessary.

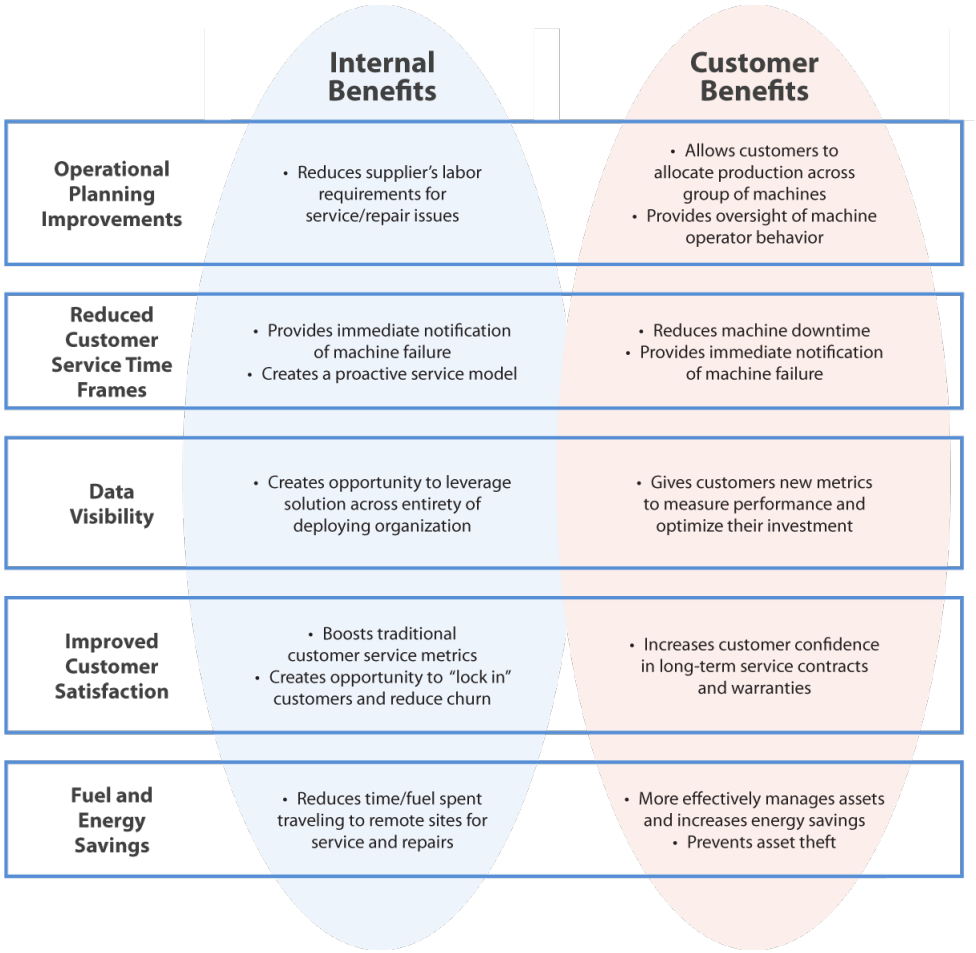
M2M solution providers must carefully evaluate their security concerns on an application-by-application basis, as a one-size-fits-all approach to security is neither necessary nor cost-effective.

Building the Business Case and Optimizing TCO

One of the most significant hurdles companies deal with when considering connected device solutions is building the business case. On one side of the equation, companies are looking toward connectivity as a way to drive additional business benefits both internally and externally. On the other side of the equation, companies are challenged with reducing TCO for their connected device investments.

From a business case perspective, most successful implementations begin with an objective of focusing on either the customer service-oriented benefits or internal cost-efficiencies. By focusing on a key internal or external pain point, companies can identify KPIs that will drive ROI. However, the benefits derived from connected device implementations also cut across both internal and external (customer) metrics (see Exhibit 7).

Exhibit 7: Deployer and End-User Benefits of Connected Device Deployments
Source: Yankee Group, 2011



When estimating the TCO of M2M deployments, enterprises tend to focus heavily on immediate hardware and connectivity costs. Yankee Group research shows that these costs are a relatively small component of an M2M deployment's TCO. According to previous Yankee Group research, module prices have plummeted 66 percent over the past five years, and recurring data costs for the average M2M connection have fallen to just $3.52 per device per month. Data fees for low-bandwidth M2M applications have seen particularly sharp decreases in recent years.

Platform services that empower enterprises to monitor and manipulate devices are another TCO component. According to previous Yankee Group research, advanced platform management services are often priced at a 10-15 percent premium to network connectivity, representing a substantially larger portion of ownership cost. M2M solution providers that can consolidate advanced platform services such as device management and provisioning, billing, security, application development and back-end integration will provide enterprises with a means of effectively managing their TCO.

The most expensive portion of an M2M deployment comes from design, integration, manufacturing, approvals and installation costs levied during the initial deployment phase. Without a well-crafted implementation procedure, M2M deployments can easily become bogged down by redesign requirements, back-end integration difficulties or a lack of compatibility between hardware and software components. As a result, successful M2M deployments leverage platform partners with experience navigating these hurdles.

Innovation centers can also help. AT&T's M2M innovation center and Alcatel-Lucent's ngConnect program are examples of collaborative environments where hardware, software and platform providers can work together to address enterprise needs on an individual deployment basis. By facilitating collaboration, innovation centers can patch together all the necessary components of a solution and help develop business models and deployment plans. Additionally, innovation centers play a crucial role in both educating enterprises on M2M technology and reducing time to market for new solutions.

Real-World Applications

Although new connected device use cases are born each day (even an embedded mousetrap exists), several connected device applications have already witnessed widespread deployment. In fact, in a few key verticals, M2M deployments have matured from fringe pet projects to imperative links in a business' operations.

M2M deployments in the health care and energy verticals have already redefined existing processes, improved efficiency, created cost savings and enhanced the end-user experience. Fleet management applications keep drivers honest, optimize their routes, save money and lower insurance costs. Even new devices such as digital signs and connected parking meters empower more efficient business models and open the door to new revenue streams.

OEMs catering to consumers also get the picture. Embedded connectivity allows manufacturers to sell media and value-added services to consumers well after a device leaves the manufacturing floor. Moreover, devices with WAN connectivity work right out of the box, eliminating the need for consumers to struggle with their home networks.

This section highlights enterprise verticals affected by M2M and discusses how embedded connectivity has changed the way consumers interact with their devices.

Enterprise Applications

Fleet Telematics

Solution providers have been connecting fleet vehicles for more than a decade. While many legacy fleet tracking systems have utilized satellite connectivity for their deployments, increased cellular coverage and decreased hardware prices have precipitated a mass migration to dual-band or pure cellular networks. Yankee Group expects cellular connections used for fleet management purposes in the U.S. to grow from about 3.6 million today to 7.5 million by 2015, a CAGR of 16 percent.

Applications and Use Cases

The immediate savings gleaned from route optimization and improved machine maintenance processes got trucking companies hooked on fleet management applications more than a decade ago. Initially, simple location-based tracking applications drove many trucking companies to connect their assets. These applications empowered fleet managers to accurately set both time tables and delivery schedules while accommodating vehicles ahead of or behind schedule. GPRS connectivity provides plenty of bandwidth and latency to support these use cases.

Today, these applications have expanded to track engine performance, analyze driver behavior and monitor the state of a truck's cargo. Trucking companies now understand the exact inventory of cargo being towed, the condition of the cargo (temperature, wet/dry, etc.) and the state of trailer door (open, closed, locked). Moreover, since trailers are often switched between cabs, embedding the trailer itself ensures a direct connection to the cargo. Tapping into a truck's electronic control unit and diagnostic systems does create hardware challenges. M2M modules used in the transportation industry typically need to last between seven to 10 years to adequately serve a vehicle's life span, and thus often require ruggedization. For example, Cinterion has worked closely with Bosch to design telematics monitoring units with automotive-grade connectivity, glass-reinforced plastic and an internal power source to attach to trailers. On the network side, a more robust HSPA connection can help support multiple applications running simultaneously on the same truck.

In the future, many use cases for higher-bandwidth connections within fleet management will exist. For example, UPS and FedEx drivers often leave the back door of their trunks open while making deliveries, leaving their cargo susceptible to theft. With mobile broadband powering surveillance in the trailer, motion sensors could trigger a video feed of the cargo area to identify the culprit. The same concept could be utilized inside construction equipment to visually monitor an operator's behavior. HSPA+ networks can presently meet the data requirements of these applications, and LTE networks will further enhance these services when the networks become more readily available.

Heavy construction equipment has proved another fertile ground for M2M adopters. In an effort to remain competitive, major OEMs—including Caterpillar, Komatsu, John Deere and Volvo Construction—have embedded connectivity into their equipment. Connectivity not only helps OEMs deliver higher levels of customer service when repairing and maintaining equipment, but also empowers construction fleet managers to proactively manage their assets.

Benefits Realized

Companies that deploy fleet management applications often realize a rapid ROI in the form of reduced fuel costs, greater productivity, safer drivers and more efficient distribution channels (see sidebar at right). Enterprises with fleet telematics solutions can further maximize their benefits by pairing their technology with an inventory management system.

In the heavy construction industry, connected fleet technology creates incredible benefits for end-users. While the OEM can offer advanced SLAs and guarantees through its service department, end-users gain a management tool to help manage cost, productivity, labor, safety and regulatory issues. Major equipment OEMs collaborate with one another through the Association of Equipment Management Professionals in creating a common portal for key data points from all participating OEMs to allow fleet managers with mixed fleets to view their data through a common interface.

CASE STUDY: FLEET TELEMATICS

U.S.-based trucking company Namasco supplies steel to more than 8,000 metalworking businesses throughout the country. In 2009, Namasco deployed a GPRS-based telematics solution through fleet solutions provider Telogis. Namasco chose GPRS connectivity based on strong network coverage and availability within the U.S. footprint. After connecting just 50 of its trucks, Namasco found that it saved over half a million dollars a year in fuel costs, recovered a stolen truck worth $100,000, decreased travel downtime by 53 percent and increased employee accountability by 26 percent. With these results from just the pilot group of 50 trucks, the company is keen to connect the rest of its 200-vehicle fleet.

Health Care

The U.S. spent $2.5 trillion on health care in 2009, a figure growing about 3 to 4 percent annually.[10] Health experts suggest that U.S. hospitals, emergency care facilities and nursing homes could save over $20 billion a year just by utilizing remote monitoring systems for patients suffering from chronic conditions such as heart disease, diabetes and chronic obstructive pulmonary disease (COPD).[11] These remote systems would allow patients to be monitored in their homes, reducing health care cost and freeing up valuable medical resources. Embedding medical devices, rather than requiring patients or medical personnel to manually upload data stored on the device, drastically reduces human error in the data transfer process and creates accurate information that doctors can act on with confidence.

10 U.S. Department of Health and Human Services, Centers for Medicare & Medicaid Services
11 Mobihealth News, July 27, 2009

Applications and Use Cases

Connected mHealth devices have several use cases, ranging from self-monitoring fitness/wellness type devices to mission-critical monitoring systems.

- **Fitness and wellness applications:** Fitness and wellness applications, such as connected scales or wearable heart monitors, encourage consumers to exercise and empower self-monitoring of key fitness indicators. Several fitness applications use Bluetooth, Wi-Fi or Zigbee connections to access the patient's smartphone or home cellular connection to access the Internet.
- **Remote patient monitoring:** Moving non-critical patients away from hospitals and other emergency facilities frees up resources and provides patients with care in the comfort of their own homes. As the average mHealth user expands from using one mHealth application to multiple applications, more mHealth solution providers are adopting a hub concept, using a central cellular point to communicate with several peripherals over short-range communications including Wi-Fi, Zigbee and Bluetooth. This category includes adherence applications that remind patients to take their medicines (see sidebar at right). It also includes more critical monitoring of chronic diseases or health indicators (e.g., blood pressure, heart rate). GPRS is a cost-effective connectivity solution for low-bandwidth, diagnostic applications, such as sleep apnea machines, where data can often be sent in batches. For more critical applications that require real-time monitoring, HSPA and HSPA+ provide plenty of overhead bandwidth to enable more complex mHealth applications on both a performance and encryption basis.
- **Doctor-patient consultations:** Two-way video technologies coupled with some basic monitoring devices can allow doctors to cover much broader territories, spending less time in transit and more time in face-to-face meetings with patients. HSPA+ networks are well suited to cope with the bandwidth-intensive nature of real-time video streaming applications, and LTE networks will further enhance the consultation experience.

Benefits Realized

Patients enjoy a more comfortable medical experience, avoiding hospital visits by using remote monitoring technology or traveling with a wirelessly enabled pill reminder system such as Vitality GlowCaps. Medical equipment manufacturers gain greater insight into the performance of their machines, providing the opportunity to guarantee uptime and sell advanced SLAs. Doctors benefit from tools that allow them to better serve patients and observe more accurate patient data in settings outside the hospital, which is crucial in properly diagnosing conditions such as sleep apnea. Insurance companies can more accurately assess patient risks and reward subscribers with healthier lifestyles.

CASE STUDY: mHEALTH

MHealth pioneer Vitality has developed a pill bottle system, called GlowCaps, with cellular connectivity. Embedded with a Telit GSM/GPRS module and connected over AT&T's network, the caps send visual and audio reminders, e-mail, text messages and phone calls to remind patients to take their pills. Through a beta-test run in conjunction with Partners HealthCare's Center for Connected Health, Vitality achieved a pill regimen adherence rate of over 98 percent using the caps, compared to a control group's 71 percent adherence rate without the cap.

Pharmacies and pharmaceutical companies have shown great interest in the product, since greater patient adherence means more prescriptions filled and more pills consumed, and therefore healthier people (and more revenue generated). Because the cost of each pill bottle to the pharmacy or pharmaceutical company is quickly offset by an increase in the number of pills consumed, Vitality's business model results in a rapid ROI for companies that buy into the technology and allows these players to subsidize the technology for end-users.

Transaction-Based Applications (ATM/PoS/Kiosk/Vending Machine)

The connected vending machine has opened the door for several other transaction-based applications. Embedding connectivity into PoSs and kiosks can create more efficient workforces in traditional retail environments or generate sales opportunities in previously untapped markets. By creatively utilizing connected transactional devices, organizations in several lines of business can increase the efficiency and effectiveness of their sales channels.

Applications and Use Cases

Connectivity will play a crucial role in redefining both existing legacy machines and enabling new transactional ideas. Examples include:

- **Vending machines:** Connected vending machines reduce truck rolls, decrease machine downtime and create insight into consumer preferences. Most vending applications are not data-intensive and do not often require real-time feedback, and GPRS has been a common connectivity choice. In addition, many enterprises deploying vending machines are utilizing a cluster concept in arranging a group of machines to communicate via Zigbee, Bluetooth or Wi-Fi to a central cellular hub, helping reduce transmission and hardware costs.
- **Kiosks:** A well-situated kiosk can replace a salesperson in a retail environment and provide customers with information on an item or even a video consultation to address a specific problem. Currently, HSPA or HSPA+ connections are the best choice for transactional kiosks or video streaming use cases, and significant footprint coverage allows enterprises to move kiosks without worrying about compromising network performance. As LTE becomes more pervasive, the technology will provide the low-level latency and high throughput to optimize video transmission.
- **PoS terminals:** A wirelessly-enabled PoS terminal allows more employees within a store to process sales, decreasing lines at the cash register and increasing the value of each employee. Mobile PoS terminals also allow retailers to set up mobile storefronts at outdoor venues such as sports stadiums or seasonal events such as fairs and festivals. Most mobile PoS terminals currently use GSM/GPRS connectivity and include Data Encryption Standard (DES) and RSA security. Packets of transactional data are usually relatively small, so the main decision driver in choosing connectivity is network availability.
- **ATMs:** Although many ATMs at bank branches currently utilize fixed-line connectivity, cellular connections allow easy ATM placement in hotel lobbies, malls and convenience stores where secure LAN connectivity is less readily available or costly to install. For financial institutions, converting on-premises ATMs to use wireless connectivity can reduce costs, but it also introduces security challenges. For example, cellular ATMs within a bank branch must be insulated from Wi-Fi access to ensure no one can access or compromise ATMs via a personal device. As a result, several wireless ATM manufacturers are employing SSL encryption or IPsec to secure data at the network layer. As with PoS terminals, transactional packets are relatively small in size, so GPRS and UMTS connections are suitable to serve most ATMs. HSPA+ or LTE connections will likely speed transactions by a few seconds, and they could empower other applications on the ATM, such as video surveillance or on-screen advertising.
- **Parking meters (see sidebar at right):** To the average driver, the only tangible benefit of a connected parking meter may be the option to pay by credit or debit card. In reality, a connected parking meter has enormous additional benefits to the deploying municipality. The meter allows for dynamic pricing, allowing cities and towns to charge more or less for spaces based on demand and availability at any given time or event, thereby helping reduce traffic and relieve congestion. The meters can send alerts when they have expired, greatly increasing the efficiency of the ticket-writing process. Finally, in addition to greater payment flexibility, the connected parking meter can create visibility for drivers by mapping which spaces are open through an online interface.

CASE STUDY: CONNECTED PARKING METERS

The city of Los Angeles deployed more than 10,000 IPS cellular parking meters over a three month span in 2010, replacing about a quarter of the city's estimated 40,000 meters. The meters were embedded with a 2.5G Telit GPRS module and supported by the T-Mobile network. Due to the substantial size of the deployment, GPRS modules provided a low-cost connectivity solution but were still robust enough to securely manage transactions and frequent meter status updates. After only six months, the city noted an increase of 14 percent meter uptime due to a more efficient repair process. Contested meter citations plummeted 75 percent, and complaints to the city's meter hotline fell 50 percent. The city plans to double the size of its connected meter deployment and expects a subsequent net revenue increase of $3.5 million. IPS claims to have a TCO almost 40 percent less than that of a multi-space pay system over a five-year period. In addition, connected parking meters provide hotspots or gateways to connect sensors on other assets, such as streetlights or traffic signals, through Wi-Fi, Bluetooth or Zigbee connections.

Benefits Realized

Transaction-based applications gain tremendously from wireless technology because mobility enables deployers to shift their assets to high-traffic areas or areas where building fixed-line connectivity would be costly. In addition, transaction-based devices benefit from a service-repair standpoint and enjoy increases in uptime by immediately alerting technicians when a problem occurs. Mobile PoS terminals can increase workforce productivity. Finally, embedding wireless connectivity into ATMs provides much greater security through applications such as video surveillance and location tracking in the event of theft.

Energy

Connected energy represents one of the largest potential markets for connected devices, with millions of households and enterprises with electricity and water needs throughout the U.S. Although the U.S. smart metering industry lacks some of the government smart grid initiatives enjoyed by many European countries, several utilities are deploying smart grid solutions and working closely with 3GPP operators and network builders in either building out their own private networks or building agreements to connect meters on public networks. While it is too early to say which type of network ownership will ultimately win out, connected devices will irrefutably play a crucial role in building the smart grid infrastructure.

The technology of choice in today's smart grid industry varies by region. Whereas European utilities have used power line communications (PLC) in their deployments, early U.S. deployments have relied on RF mesh networks and have used cellular to backhaul data to back-end systems. In both regions, however, more utilities are leaning toward embedding a cellular module behind the glass of each meter for three main reasons:

- **Cost.** Utilities find private networks incur massive capital and maintenance costs. In addition, according to Yankee Group research, some wireless carriers have dramatically reduced the cost to connect a meter to about 35 cents, a move that makes cellular deployments much more fiscally viable. Moreover, utilities working with network operators can benefit from automatic network upgrades, rather than bearing the burden of upgrading private networks.
- **Increased bandwidth.** While RF mesh networks and PLC deployments can support automated meter reading (AMR), they are not robust enough to support advanced demand response and distribution automation applications.
- **Better reliability.** Meters connected via a cellular connection can provide invaluable data to utilities during a power outage or when PLC systems experience problems. While some critics argue that moving smart grid traffic to public networks increases the risk of data corruption, smart grid data is sent on separate channels on public networks, ensuring its integrity and prioritization over other data. Additionally, in a state of emergency, utilities can prioritize power restoration while carriers focus on restoring network service.

Applications and Use Cases

While simple remote monitoring applications currently dominate the connected energy space, robust network connections and hardware could support more complex applications in the future.

AMI is the most basic function of many current smart grid deployments; rather than having a person physically read the meter, the meter automatically transmits consumption back to the utility to generate a bill. The amount of bandwidth required for the transmission of such data is quite modest: According to cellular smart meter provider SmartSynch, if all 300 million meters in the U.S. transmitted a day's worth of data at 15-minute intervals, the additional traffic would only result in an increase of less than 2/1,000 of 1 percent in the amount of data an operator such as AT&T carries on its network on a daily basis. Since 3GPP technologies allow smart grid manufacturers to market their product globally, GPRS and UMTS are effective connectivity choices for AMI and other utility applications, including the following:

- **Distribution automation and control:** With connected meters, utilities can more efficiently shift power to shorten blackouts/brownouts or address power outages. HSPA and HSPA+ should provide additional bandwidth overhead for these more data-intensive operations, and the improved QoS standards included in LTE networks will help ensure the proper prioritization of smart grid data on public networks.
- **Load profiling:** Connected meters can empower utilities to change pricing based on time of day, encouraging consumers to use power in off-peak hours.
- **Substation automation:** Cellular connectivity can be used to monitor the core infrastructure assets of utilities and ensure their integrity from both a security and efficiency standpoint.

Benefits Realized

Utilities realize the most benefits from smart grid deployments, as they are able to more efficiently manage their power grids and increase uptime, as well as more accurately bill power consumers. Utilities are also able to significantly reduce labor costs by using AMI technology and eliminating the need to manually read meters. Eventually, customers should enjoy greater control over electric usage and more flexible billing plans that match their consumption patterns. In-home displays or head units could allow customers to interact with the data stream of their energy consumption and determine ways to reduce electricity and water use, lowering their bills at the end of the day.

Digital Signage

As one of the more nascent vertical markets, digital signage will grow dramatically in concert with lower HSPA+ hardware costs and greater LTE pervasiveness. Connected digital signage will have a significant impact on the advertising industry as well as the specific environments in which the signs are displayed.

Applications and Use Cases

Regardless of whether digital signage is replacing more traditional advertising or enabling new creative use cases, the use of HSPA+ and LTE technology to replace print advertising or hard-line connections will reshape advertising methods and media. Because both static and dynamic imagery requires substantial bandwidth overhead, HSPA+ and LTE connections with low latency and high throughput are the most effective technologies to use to transmit digital signage data. Digital signage can vary from commercial-grade television screens in a retail environment to multi-million-dollar scoreboards in sports stadiums across the country.

- **Traditional signage replacement (billboards, etc.):** Wirelessly connecting billboards eliminates the tremendous cost and material waste of manually tearing down an old billboard and installing a new one.
- **Retail environments:** Often used in concert with kiosks, digital signage allows retailers to target advertising to specific products or even customers through interactive profiling. In big-box stores, wirelessly-enabled digital signage empowers individual manufacturers to manage their specific product's advertising with no dependency on in-store connectivity.
- **New environments:** With wireless connectivity, digital signs can be placed anywhere, including taxi cabs, buses, trains and even bathroom mirrors. The mobility of wirelessly-enabled signs allows advertisers to shift their deployments based on foot traffic or event cycles.
- **Public service announcements:** Roadway signs, speed warning signs and announcement boards in government buildings are all great candidates for digital replacement, as digital signage would provide greater security and portability.

Benefits Realized

Embedded digital signage creates a much more dynamic experience for consumers, grabbing their attention and exerting greater influence over their purchasing decisions. Advertisers and retailers can target advertisements for specific times of day and update advertisements more frequently to prevent content from becoming stale. Interactive touch-screen signage can help identify purchasing trends and demographics. Because embedded digital signage can be repurposed for different products, promotions, customers, locations and occasions, they can significantly reduce the high cost of creating print advertisements. In addition, retailers or stadium owners that install digital signs can resell advertising space to multiple suppliers.

M2M Connections Represent a Substantial Market Opportunity

Exhibit 8 on the next page summarizes the cellular opportunity in several key verticals around the world. The exhibit includes vertical markets not touched on in this report, including industrial, security, pay-as-you-drive insurance and rent-to-own/subprime lending applications. Overall, Yankee Group expects enterprise M2M connections worldwide to nearly triple from 81.3 million in 2011 to 219.2 million in 2015, a CAGR of 22 percent.

Consumer Applications

Consumer Telematics

More than 250 million passenger vehicles ride the U.S. highway system. But until recently, most came off the assembly line disconnected and unintelligent. In the past two years, however, in-vehicle telematics systems have changed the way consumers interact with their cars.

Exhibit 8: M2M Connections for Enterprise Applications Worldwide, 2011-2015
Source: Yankee Group, 2011

Category	2011 Cellular Connections	2015 Cellular Connections	CAGR	Monthly ARPU 2011/2015	Factors Affecting Growth Rate
Consumer Telematics	19.8 million	34.1 million	11%	$3.84/$4.27	Adoption by major automotive manufacturers
Fleet Telematics	6.4 million	14.5 million	18%	$4.39/$4.26	Increased use of cellular over satellite-based technology
Industrial Applications	17.5 million	30.7 million	12%	$5.32/$4.56	Lower hardware costs and clear service benefits
Security Applications	12 million	18.3 million	9%	$1.72/$2.62	High-bandwidth streaming for surveillance applications; application layering
Vending/ATM/ PoS/Kiosk	12.6 million	28.5 million	18%	$1.73/$1.72	Clear ROI from reduced truck rolls and repair expenses; mobilization of sales forces in retail environments
Connected Energy	9.2 million	77.3 million	53%	$1.56/$1.32	Continued government smart grid funding/initiatives; increased bandwidth overhead with cellular technology for advanced applications
Rent-to-Own/ Subprime Lending	1.3 million	2.6 million	15%	$1.03/$0.87	Very nascent market segment; increased confidence among lenders if asset recovery technology proves successful
Pay-as-You Drive Insurance	960,000	9.4 million	58%	$4.68/$3.97	Major insurance companies should follow Progressive's lead
mHealth	815,000	1.7 million	15%	$4.04/$3.98	Possible government initiatives for electronic health records; establishment of open standards
Digital Signage	699,000	2.1 million	25%	$12.16/$11.86	Cellular digital signage opens opportunity for new sign locations and maneuverability; cheaper connectivity
TOTAL M2M	81.3 million	219.2 million	22%	$3.36/$2.89	

GM's OnStar, Nokia's Terminal Mode and Microsoft's Auto platforms have pioneered consumer telematics solutions that bundle together three components:

- **Network connectivity:** Today's telematics solutions leverage either embedded connectivity or a bring-your-own-broadband model to get vehicles connected. In 1995, OnStar made waves by offering navigation, emergency and communications services through an embedded module. This fall, BMW will take embedded telematics solutions even further with its ConnectedDrive product. ConnectedDrive will use GSM networks to provide real-time traffic information to consumers struggling to avoid traffic congestion. Ford has pioneered a different connectivity model: The Ford Sync helps consumers share their smartphones' data plan with their cars via Bluetooth tethering. Once consumers have tethered their smartphones, the Sync system lets users control applications running on their handsets with in-car embedded systems.
- **In-vehicle embedded systems:** Today's consumer telematics solutions tightly integrate with a vehicle's embedded systems to either deliver or collect data. For instance, vehicle health reports run on Ford's Sync platform collect operational data from sensors residing on a vehicle's major electronic systems. Alcatel-Lucent's LTE ngConnect concept car leverages a vehicle's in-dash display and speaker system to deliver multimedia content (see sidebar at right).

CASE STUDY: CONNECTED CAR

In 2009, Alcatel-Lucent led a consortium of companies to launch the LTE Connected Car concept. The ngConnect concept car features an LTE module that provides always-on access to the Internet, entertainment applications and real-time navigation services.

In November 2009, Alcatel-Lucent tested the appeal of the connected car with consumers by surveying thousands of respondents in the U.S., Europe, Middle East and Africa.

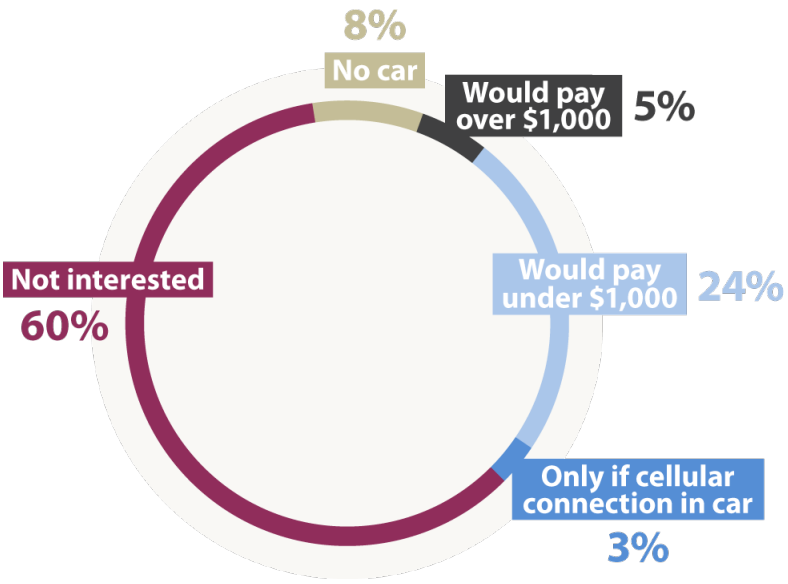
The concept was a hit. Of the 2,158 respondents in the U.S., nearly 60 percent found the concept either "very appealing" or "appealing."

Moreover, the average consumer expressed interest in paying a stand-alone fee of $65.54 a month for connected car services. Consumers would also pay nearly $30 if service providers bundled the fee with their existing mobile subscription.

- **Next-gen applications:** Telematics solutions don't just collect and receive data. They also synthesize data to deliver compelling applications. Fiat's ecoDrive application collects data on consumer driving habits, then synthesizes and reports on this information on an online platform accessible from any Web browser. NgConnect's Connected Car runs Pandora, Kabillion and TuneWiki applications from the in-dash console.

Consumers have already expressed substantial interest in these offerings. As part of its 2011 US Consumer Survey, Yankee Group asked respondents to evaluate their interest in paying upfront costs for a voice-controlled telematics system that would let them tether their handsets to their cars and play movies, stream music, upload personal media and get restaurant recommendations. The responses are summarized in Exhibit 9.

Exhibit 9: 29 Percent of Consumers Express Interest in Telematics
Source: Yankee Group, 2011

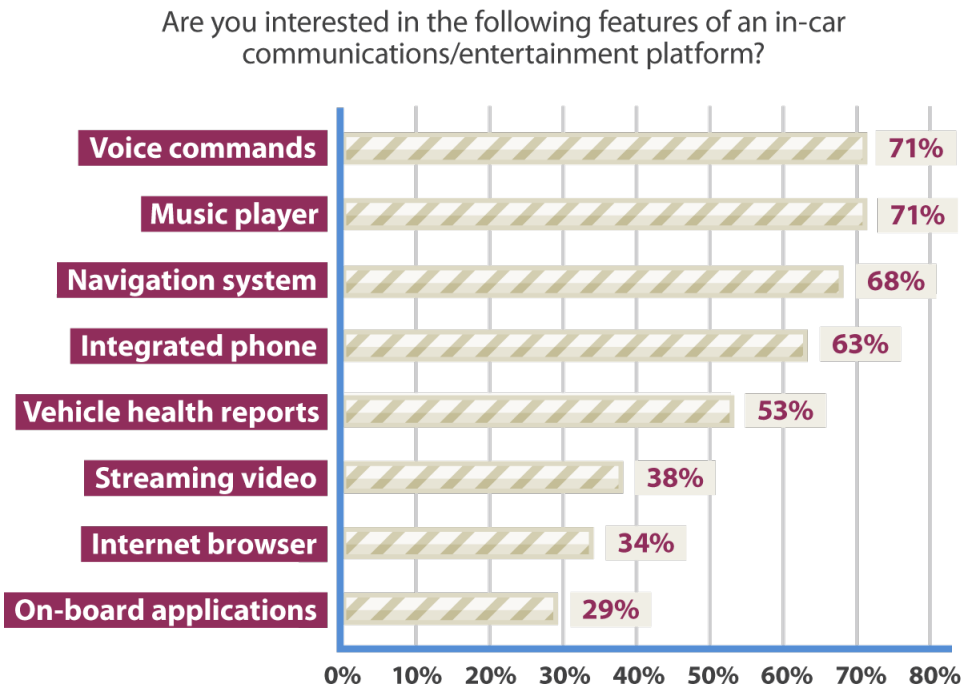


Nearly a third of consumers would invest in a telematics platform for their cars, although most are only willing to pay less than $1,000 to get their platforms up and running. Key demographics show even greater interest: More than 48 percent of 25- to 34-year-olds express interest in a telematics platform.

Moreover, a handful of consumers have already begun clamoring for embedded connectivity; 3 percent of survey respondents would only invest in a telematics platform if automotive OEMs baked in connectivity.

Once their cars get connected, how will consumers use telematics platforms? Yankee Group asks a follow-up question to gauge interest in telematics features. Consumer responses are shown in Exhibit 10 on the next page.

Exhibit 10: Consumer Telematics Use Cases
Source: Yankee Group, 2011



Music players, navigation systems and vehicle health reports all pique respondents' interest. Moreover, bandwidth-intensive features such as on-board applications, streaming video and Internet browsing show high potential.

Based on Exhibit 10, Yankee Group concludes:

- **Consumers can't get enough streaming media.** More than 70 percent of consumers express interest in streaming music from over-the-top providers such as TuneWiki and Pandora. Moreover, streaming video intrigues nearly 40 percent of consumers. LTE will ensure that these consumers get the multimedia they want without speed or latency issues.
- **Vehicle health reports will benefit from embedded connectivity.** More than half of respondents indicate interest in vehicle health reports from a telematics solution. Today's solutions, such as Fiat's ecoDrive, require consumers to walk their vehicle data from car to computer via a USB drive. Tomorrow's solutions will use embedded connectivity to automatically sync vehicle data with an online platform accessible to consumers. At CES 2011, Ford showcased the benefits of embedded connectivity in its line of electric vehicles. When it launches in late 2011, the Ford Focus Electric will come bearing a GSM module that allows consumers to monitor their vehicle's charge on a mobile device, charge their vehicle during off-peak hours and pinpoint charging stations.
- **Application stores' and Internet browsers' time will come.** Consumers have shown insatiable appetites for application stores on mobile phones and high-definition televisions (HDTVs). For the moment, however, lack of location-based applications is tempering short-term demand for in-car app stores. Still, more than 25 percent of consumers show interest in on-board applications. Embedded connectivity will enable developers to leverage the wireless network to come up with innovative applications for the road.

Two factors will make 3GPP technologies particularly attractive to automotive OEMs targeting consumers. First, consumer automobiles have long life cycles. In fact, a 2010 R.L. Polk study pegged the median age of vehicles on U.S. roadways at 10.2 years. As global carriers consider re-farming 2G spectrum, wise OEMs will choose a network technology that will stand the test of time. LTE provides automotive manufacturers with a future-proof telematics solution that supports even the highest-bandwidth consumer applications. Second, automobiles cross international borders. The scope of international GSM deployments will help consumers roam internationally without service interruption.

Education

A bevy of manufacturers have already positioned their tablets and e-readers as learning tools for students. School administrators have taken the bait:

- **School administrators are trialing tablets.** In 2011, Brainchild launched the Kineo, an Android tablet that allows school administrators to pre-approve applications and Web sites students can access. The OEM sold out of its initial production run of 5,000 devices as school districts in 10 states turned out in droves to trial the device. Apple's iPad is also attracting substantial attention. New York City Public Schools have spent more than $1.3 million bringing iPads to their students. In Chicago, more than 200 schools applied for 23 grants that would provide iPads to students. These grants represent an investment totaling half a million dollars. Many of these school districts have elected to pilot iPads with an embedded High-Speed Downlink Packet Access (HSDPA) module to keep students connected when they leave school grounds.
- **Major universities are evaluating e-readers.** In 2009, Arizona State University, Princeton, Pace University and the University of Virginia all handed out Amazon Kindles to a subset of their student population. The devices were a hit. Administrators saved on printing costs: Princeton students printed out 85 percent fewer course materials thanks to their e-readers. Students saved on textbook costs: Arizona students using e-readers spent 75 percent less on textbooks over the course of two semesters. Moreover, students could now download reading material anywhere, thanks to an embedded HSDPA modem in each Kindle.

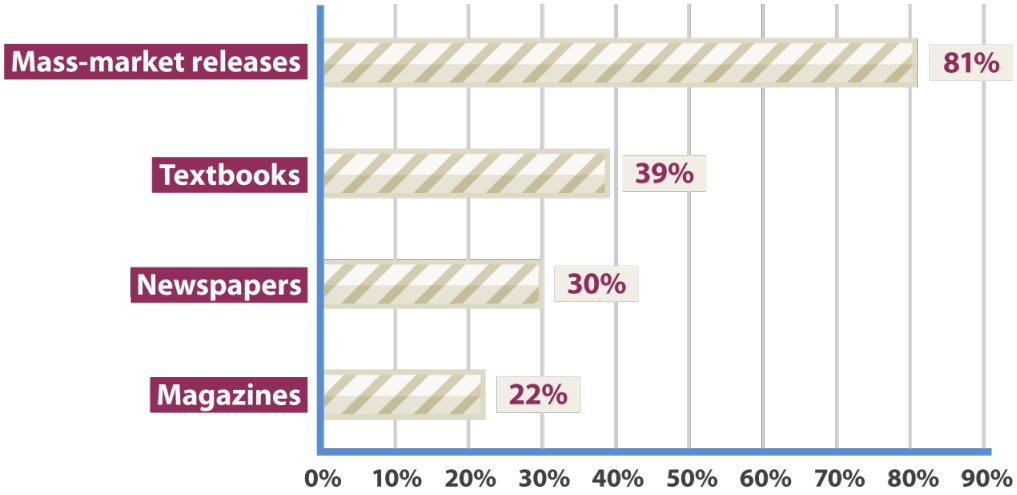
Applications and Use Cases

CourseSmart, Barnes & Noble and Kno have all launched e-textbook stores catering to students and school administrators. Kno offers more than 70,000 e-textbooks at a 30-50 percent discount off cover prices. CourseSmart offers nearly 15,000 and boasts an average savings of more than $66.59 per textbook. In July 2011, Amazon followed suit by launching its own textbook rental service.

Consumers have already responded to these offers. Yankee Group's 2011 US Consumer Survey asked e-reader owners to evaluate their interest in a range of e-print publications on a scale of 1 to 10. Exhibit 11 graphs top-three box responses.

An overwhelming majority of consumers will use their e-readers to read mass-market paperbacks and hardcovers. But the importance of e-textbooks should not go unnoticed. More than 40 percent of e-reader owners gush over e-textbooks. In fact, e-reader owners show more interest in e-textbooks than they do in newspapers and magazines.

Exhibit 11: E-Reader Owners Favor Textbooks Over Newspapers
Source: Yankee Group, 2011



But e-textbooks are just the beginning. Several developers are creating educational software specifically designed for students:

- **Teachers have a new way to teach algebra.** In June 2011, Houghton Mifflin Harcourt announced a year-long pilot program for its HMH Fuse, a digital math program. The software provides students with step-by-step animated instructions and instant feedback as they solve math problems. The application also allows teachers to actively monitor their students' performance and provide feedback over the Web.
- **Administrators have new ways to monitor students' performance.** Brainchild has packaged its Achiever! software into all of its Kineo tablets. Achiever! assesses students' performance against state standards on subjects including mathematics, language arts and sciences. It then delivers tutorials and re-tests students on problem subjects. Brainchild collects data on students' progress and aggregates it on a portal that administrators and teachers can access.

WAN-connected devices will become essential to school administrators who want full control of their students' learning experience:

- **WAN devices keep administrators in control.** WAN connectivity offers administrators the ability to manage and update their students' devices over the air. Administrators who opt to deploy Wi-Fi-only devices will need to prompt the device user every time a new update is available. WAN connectivity eliminates this need, making life easier for administrators and students alike. WAN connectivity will also give administrators more visibility into how students use their devices. M2M platforms will give administrators the ability to adjust their policies in real time. Students should stay focused on their assignments, not on the latest YouTube sensation.
- **They enable learning outside the classroom.** According to Yankee Group's consumer survey, more than 41 percent of U.S. consumers don't have a wireless network set up in their homes. Administrators who send their students home with Wi-Fi-only devices will potentially leave some of them high and dry. WAN connectivity will allow students to access their coursework wherever they go (see sidebar at right). Moreover, it eliminates the need for families to manage their home networks and diagnose connection problems.

Implications of LTE Technology

Today's e-books contain little more than text, so they come with small file sizes. However, several publishers have begun creating e-textbooks that integrate audio, video and text into one cohesive learning experience. Delivering these larger files to students' devices will require LTE or evolved HSPA+ networks. Realizing this trend, players within the publishing space are making plans to effectively utilize greater network capabilities:

- **Content developers place their bets on interactive e-books.** Sesame Street offers e-books with audio narration, sound effects, music and animation. It says it hopes to one day offer interactive e-books with which children can "play along."
- **Enhanced content platforms have arrived.** Sideways and Vook both offer platforms that allow authors to embed audio and video into their text. Vook has already signed deals with a range of content partners including NBC, Simon & Schuster, ABC and Hay House. Publishers have already released more than 62 "vooks" with embedded audio and video content through distributors such as iTunes and Amazon. Many have files sizes exceeding 200 MB.

CASE STUDY: EDUCATION

In 2010, the Notre Dame ePublishing Working Group (NDPG) launched a pilot program to evaluate the impact of e-books and tablets on education. The group gave tablets to 40 students taking a seven-week course in law and management. Each tablet came with an embedded HSDPA connection that fell back to EDGE when students moved out of a 3G coverage area.

The working group found three reasons for administrators to consider these emerging technologies:

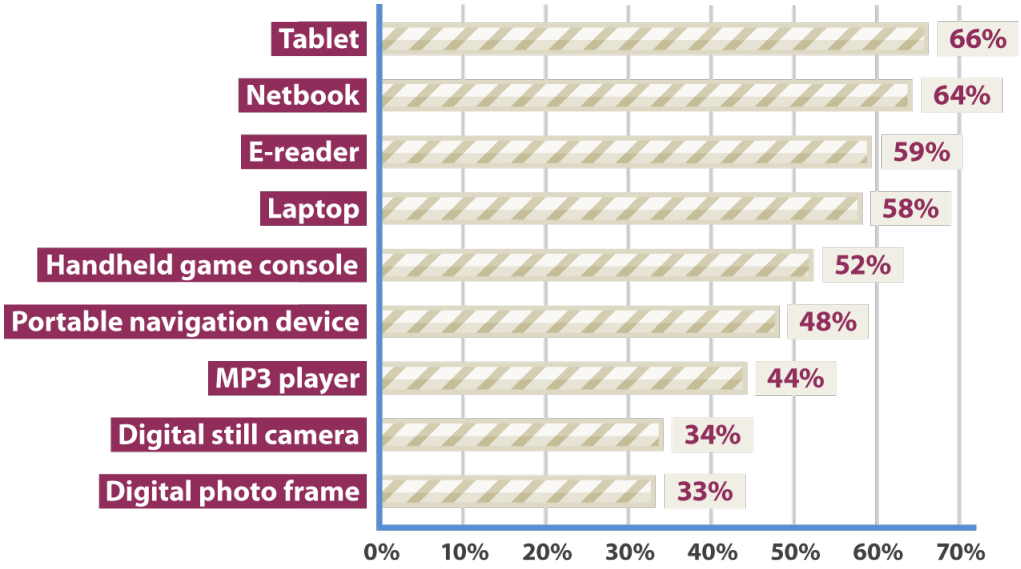
- **Tablet users curtail printing.** Students at the University of Notre Dame regularly receive course materials in digital format and print those materials before they read them on a computer screen. However, more than 70 percent of students participating in the NDPG trial substantially curtailed their printing. Savings from printing costs can add up. In 2010, the Office of Information Technology at Princeton University estimated its students print more than 50 million sheets of paper each year. This adds up to an annual cost of $5 million.
- **Tablet users find material more engaging.** Students surveyed after the completion of the study said tablets helped them learn more, made course content more interesting and encouraged exploration of additional course topics.
- **Students use tablets extensively.** Participants did more than 90 percent of their course readings on their tablets. When professors digitized all of their course materials, this number rose even further. In one of the management courses surveyed, students did 99 percent of their reading on their tablets.

Consumer Electronics

The steep adoption curves of today's consumer electronics devices continue to make headlines. The Apple iPad 2 sold a million units in its debut weekend, Nintendo's 3DS sold 3.61 million units within 34 days of launch, and Microsoft's Xbox Kinect reached the 1 million sales threshold in just 10 days.

However, the bigger story lies in the role embedded connectivity plays in selling these devices. In Yankee Group's consumer survey, respondents assess the importance of Internet connectivity across a range of form factors on a 10-point scale. Exhibit 12 plots the percentage of responses marked 8, 9 or 10.

Exhibit 12: Consumers Crave Connectivity
Source: Yankee Group, 2011



Whether connected through Wi-Fi or the WAN, consumer electronics increasingly look to embedded connectivity to keep customers happy:

- **Computing devices thrive on embedded connectivity.** Tablets, netbooks and laptops just aren't the same without Internet connectivity. In fact, nearly 70 percent of consumers say connectivity is indispensible on their tablet and netbook devices.
- **Connectivity has created new product categories.** Manufacturers introduced e-readers and digital photo frames just a few years ago, but consumers already depend on connectivity in both devices. In fact, a third of consumers can't live without connectivity in their photo frames and 60 percent of e-reader owners state that always-on connectivity helped drive their purchase.
- **Smartphones challenge older device categories.** More than half of respondents indicate connectivity represents a crucial part of their handheld gaming experience. Handheld game console manufacturers are finally catching on. In January 2011, Sony unveiled a 3G version of its PlayStation Portable planned for launch on NTT DoCoMo's UMTS network. WAN connectivity will help handheld consoles better compete against smartphones running gaming applications.

WAN connectivity offers a host of applications and features not available through Wi-Fi. WAN modules enable consumer electronics devices to create new experiences for users, including:

- **Tracking devices spark consumer interest.** In 2010, Yankee Group asked consumers about their interest in paying $5 a month for family tracking services. Nearly 20 percent of consumers expressed strong interest (8, 9 or 10 on a 10-point scale). At CES 2011, Garmin responded by launching the GTU 10, a tracking device that leverages GSM connectivity to help parents keep their kids safe. Consumers can track the GTU 10 on their computers or mobile devices and receive alerts when children or pets leave a predefined geo-fence.
- **E-readers get consumers reading anywhere.** Back in 1999, Amazon filed a patent for 1-Click, a system that allows consumers to place an online order without the need to re-enter their shipping and billing information. 1-Click helped consumers buy on impulse. WAN connectivity on e-readers has helped Amazon extend impulse purchasing to the e-book space. By embedding connectivity in e-readers, Amazon has helped consumers buy books wherever they are, whenever they need them (see sidebar at right). The results speak for themselves. In late 2009, Amazon CEO Jeff Bezos told investors that as soon as consumers purchase a Kindle, they read 1.7 times more books. In fact, Yankee Group expects embedded connectivity in e-readers to push sales of e-books from a 2009 low of $313 million to more than $2.7 billion by 2013.
- **A third of tablets ship with embedded connectivity.** Sixty-three percent of tablet owners use their device to watch video at least once a week, and 33 percent watch video daily. To satisfy tablet owners' appetites for multimedia, OEMs have rushed to build their own video delivery platforms. At MWC 2011, HTC leveraged its Saffron Media acquisition to launch HTC Watch, Samsung launched Media Hub and Acer revamped its Alive platform. Each OEM leverages WAN connectivity to make these platforms sing. Cloud storage enables consumers to purchase video and access their video libraries whenever and wherever they need a media fix. Thanks to these delivery platforms, consumer demand for connected tablets is growing. In fact, Yankee Group's consumer survey finds that more than 33 percent of all tablets ship with embedded connectivity.
- **Digital photo frames go premium.** Digital photo frame manufacturers are leveraging the WAN to help their frames stand out in the crowd. By packing in WAN connectivity, manufacturers ensure their frame works right out of the box and consumers don't need to reconfigure their home networks to get their device running. Moreover, WAN connectivity allows manufacturers to better maintain a frame throughout its life cycle: OEMs can deliver software updates over the air without prompting the consumer. More ambitious OEMs use WAN-connected frames to venture into value-added services. Aside from packing a GSM/GPRS chip into its Vizit photo frame, Isabella Products helps its product stand out by creating an online platform at vizitme.com. The platform lets consumers store their photos in the cloud and send them to select devices—frames or otherwise.

Exhibit 13 on the next page sizes up just one of the many opportunities in connected consumer electronics. Yankee Group expects global e-reader sales to grow at a 51.7 percent CAGR, from just 10.7 million units in 2010 to more than 86.9 million units by 2015. More than a third of these devices will sell with embedded connectivity.

CASE STUDY: E-READERS

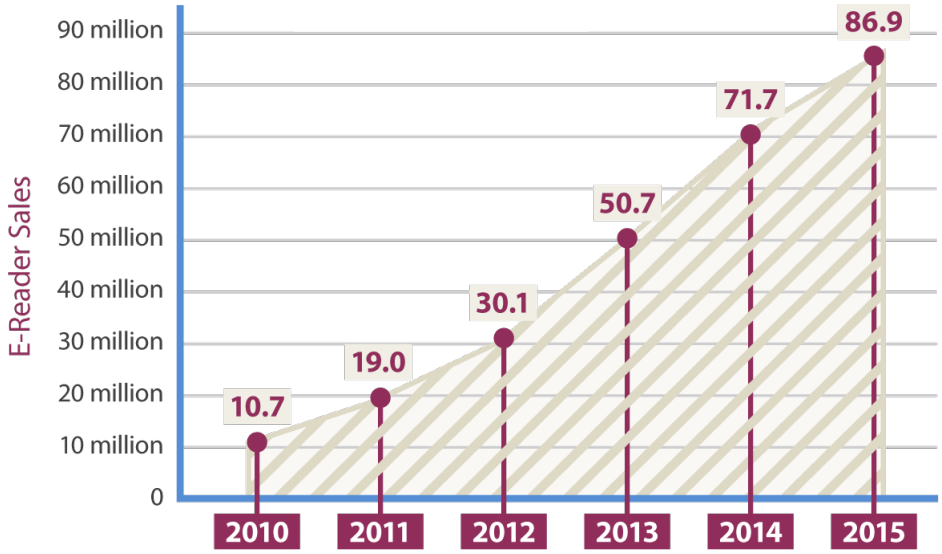
When Amazon first launched the Kindle in 2007, the company put its devices on Sprint's CDMA network. The launch was a major success for both Amazon and Sprint. In fact, in the first quarter of 2009, Sprint revealed that sales of the Kindle e-reader represented the majority of its 394,000 wholesale additions.

But the Kindle's success proved to be both a blessing and a curse for Sprint. In late 2009, Amazon's success in the U.S. market prompted it to try its luck internationally. In October 2009, it launched the Kindle International, a GSM-enabled device.

But at November 2009's Open Mobile Summit, Amazon Kindle Director Russell Baker noted that it was simply too confusing to sell one version of the Kindle that can roam internationally and one version that can't. Amazon dropped Sprint and consolidated its devices under the GSM banner.

A single GSM-enabled Kindle with HSDPA service helps Amazon scale effectively and lower prices for consumers.

Exhibit 13: Yankee Group Global E-Reader Forecast, 2010-2015
Source: Yankee Group, 2011



Conclusion

Over the past seven decades, three revolutions in computing have changed the way devices are built and sold. In the 1960s, mainframe computing helped change the way businesses processed information and led to sales of nearly a million devices across the globe. By the 1990s, technological advances helped bring computing to consumers, and manufacturers shipped more than 100 million PCs to families around the world. In the year 2000, fixed Internet access made PCs all the more valuable, and nearly a billion units floated off store shelves.

In the next 10 years, the mobile computing revolution promises even larger shipment figures. By 2020, Ericsson forecasts a global installed base of more than 50 billion connected devices. Established M2M verticals such as fleet telematics will comprise some of this growth. But hot new categories will also emerge. Yankee Group expects connected energy deployments to grow at a 65 percent CAGR to 15 million connections by 2015. Pay-as-you-drive insurance providers will add 3.4 million connections in the next four years. And consumer devices such as tablets will fly off store shelves. By 2015, nearly half a million consumers around the world will use a tablet to connect to their favorite multimedia.

By embedding cellular connectivity into their devices, OEMs differentiate their brands and keep consumers happy. According to Yankee Group surveys, more than 69 percent of consumers demand ubiquitous connectivity, and 88 percent want connectivity at broadband speeds. Businesses are also turning to connectivity to cut costs and broaden margins. Fleet management applications deployed over as few as 50 trucks can save trucking companies $1 million a year, decrease travel downtime by 53 percent and increase employee accountability by 23 percent. By connecting its parking meters, the City of Los Angeles increased revenue by $3.5 million and meter uptime by 14 percent.

OEMs moving to embed their devices will need to choose a scalable, cost-effective and high-bandwidth network technology. The 3GPP family of technologies outmuscles its peers across all three characteristics:

- **The 3GPP family of technologies provides a scalable option for connectivity.** 3GPP technologies assure global roaming capabilities for connected assets that cross borders. More than 800 operators around the world use 3GPP technologies to connect over 5.2 billion people. No other network standard boasts the same global scale. In fact, 4G Americas and Informa estimate that by 2015, 87 percent of mobile broadband subscribers will use 3GPP technologies.
- **3GPP modules are cost-effective.** Pervasive GSM networks allow 3GPP module manufacturers to scale production across large volumes. As a result, previous Yankee Group studies independent of this whitepaper estimate that GSM chipsets retail for 10-20 percent less than their counterparts. Connected device solutions involve large volumes of modules, and even small hardware price advantages can add up to a significantly decreased TCO across a deployment.
- **The 3GPP family of technologies offers the most flexible range of high- and low-bandwidth network options.** Every M2M application has unique bandwidth and latency needs. Bursty SMS apps can fare well on GPRS or GSM networks. But the 3GPP family of technologies also offers low-latency HSPA+ and LTE coverage for higher-bandwidth applications in the fleet management, security and digital signage verticals. More than 400 networks in 152 countries provide service using HSPA and HSPA+ technologies.

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Source: Yankee Group Research, Inc., Licensed Custom Product, "Mobile Broadband Connected Future: From Billions of People to Billions of Things," October 2011.

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