WHITE PAPER
Intel® Embedded Processors
The Embedded Internet

Rise of the Embedded Internet

The Embedded Internet: 15 Billion Connected Devices by 2015

Various forces, including political, economic and social, are driving the need to tightly couple embedded devices and sensors with established applications, such as healthcare, production planning and social networking. The result is the Embedded Internet, which will create new opportunities and technical challenges, many of which are addressed by Intel® silicon products and platform technologies.

Over a decade ago, the late Mark Weiser, chief technical officer of Xerox PARC, described the future vision of ubiquitous computing that is transforming our lives:

"...we are trying to conceive a new way of thinking about computers in the world, one that takes into account the natural human environment and allows the computers themselves to vanish into the background."[1]

As Weiser observed, the most profound technologies are those that seem to disappear as they weave themselves into the fabric of everyday life.

Before arriving where it is today, the Internet evolved from the first generation of connected mainframe computers to the second generation, characterized by e-commerce and email on PCs and servers, and on to the third generation, typified by social connectivity applications and the vast expansion of mobile devices.

We are now on the threshold of a fourth phase in the evolution of the Internet. Intel calls this the Embedded Internet, a network space where billions of intelligent embedded devices will connect with larger computing systems, and to each other, without human intervention. In support of this concept, John Gantz of IDC forecasts 15 billion devices will be communicating over the network by the year 2015, as illustrated in Figure 1.

The Embedded Internet will involve a massive build-out of connected devices and sensors woven into the fabric of our lives and businesses. Devices deeply embedded in public and private places will recognize us and adapt to our requirements for comfort, safety, streamlined commerce, entertainment, education, resource conservation, operational efficiency and personal well-being.

There will be adaptive and 'smart' environments, from office buildings to retail stores, that will enable innovative usage models and vastly enhanced user experiences. As a result, embedded devices will require much more capability, prompting device manufacturers to transition away from proprietary, vertically integrated embedded systems to

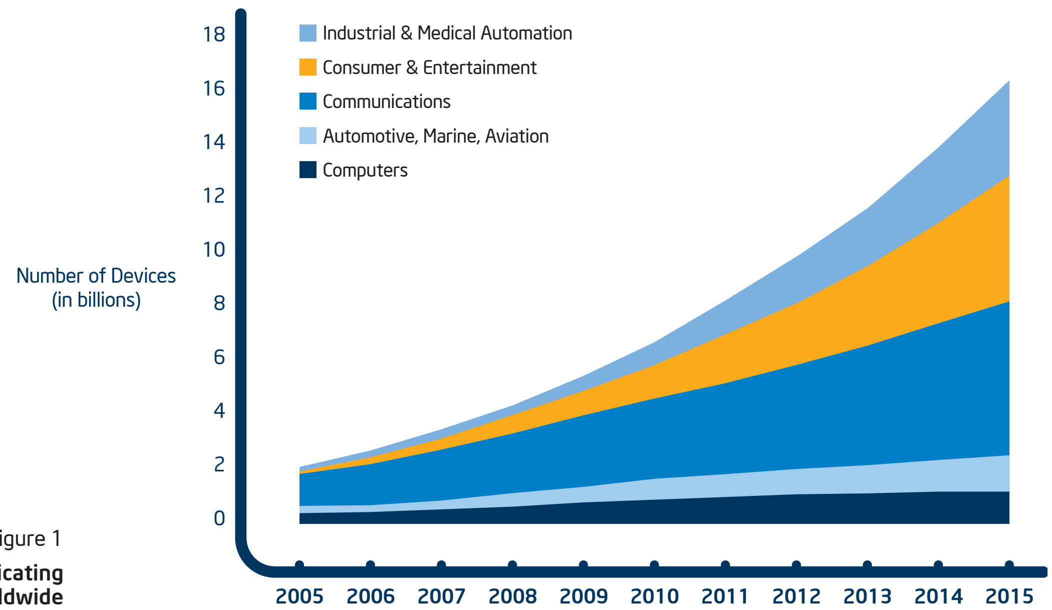

Figure 1

Devices Communicating Over a Network Worldwide

Source: John Gantz, The Embedded Internet: Methodology and Findings, IDC, January 2009 new generations of standards-based, multifunction systems. The Embedded Internet will create many opportunities for developers of new products, solutions and services. Supplying many of the necessary building blocks, Intel provides the consistent platform architecture, scalable performance and support for networking standards that will help developers quickly respond to these opportunities.

Four Underlying Driving Forces

Many far-reaching forces are driving the need to develop an Embedded Internet, some of which can be loosely categorized as political, economic, social and technological, as described in Figure 2 and in the following:

- **Political Drivers:** Legislative initiatives and regulatory incentives will require up-to-date data from embedded devices pertaining to public safety, regulatory compliance, healthcare and efficient service delivery.
- **Economic Drivers:** Organizations seeking greater process throughput, lower operating-costs and simpler asset monitoring will increase business process and manufacturing efficiency through embedded machine-to-machine communication.
- **Social Drivers:** Consumers will demand that the majority of their electronic devices (e.g., cell phones, vehicles and entertainment) ubiquitously connect to the Internet, work seamlessly and support advanced features, like voice control, which will allow people to interact with embedded machines in their immediate environment.
- **Technological Drivers:** Pervasive connectivity, enabled by inexpensive broadband technology and GPS, will allow embedded device manufacturers and service providers to deliver innovative new services and generate new streams of revenue.

Intelligent Connected Devices

Created with enhanced connectivity and interoperability, as mandated by emerging market forces, the new generation of intelligent connected devices will share some key attributes. Many will be embedded devices built to meet specific sets of application requirements, performance measures and price points. These devices will connect with others, almost invisibly, communicating machine-to-machine (M2M) as required by government agencies, consumers and businesses.

Today, network connectivity for these devices ranges from intermittent low-bandwidth connections of single-megabits or kilobits per second to persistently connected high-bandwidth-connections in the range of 10–1000 Mbps. Economic and technological drivers will push bandwidths higher at much lower cost per bit.

Device intelligence will be enabled by the application processing performance delivered by a range of platforms based on a backwards compatible architecture, from low-power Intel® Atom™ processors to Intel® Core™2 Duo processors and Intel® Xeon® processors with multi-core technology

Connected Embedded Application

The scalable performance of Intel® architecture drives new usage models and pushes the boundaries of embedded computing and communications, as shown in Figure 3.

Military: Radar and moving target indicator applications, running on Intel Xeon processors, will accurately locate targets in cluttered urban backgrounds and detect and monitor enemy positions, regardless of target movement speed.

Medical: Metropolitan fire departments and ambulance crews will use the latest embedded technologies in compact mobile diagnostic equipment, based on Intel Core 2 Duo processors, to securely transmit vital signs and diagnostic data in real time to doctors waiting at hospitals.

Industrial: New generations of intelligent multi-axis robotic arms powered by Intel Core 2 Duo processors will incorporate 3D machine vision and video analytics software to improve manufacturing process efficiency, while making the factory floor a safer place for human workers.

Retail: Handheld point-of-sale (POS) terminals, based on embedded Intel Atom processors, will help bring vitally needed low-cost banking services to remote villages in India and other developing nations.

Drivers of the Embedded Internet	
Political	**Legislative Initiatives & Incentives:** Broadband, E-Governance, E-Call, Smart Metering, E-Health
Economic	**Operational Efficiency:** Increased ARPU, lower TCO, increased Productivity
Social	**Smart Spaces:** Intelligent networked embedded devices adapt to human needs, RFID, video analytics, speech recognition and other sensing applications
Technological	**Pervasive Connectivity + Compute Growth:** LTE, GSM, WiMAX, WiFi, Bluetooth*, ZigBee, Z-Wave*

Figure 2

Drivers of the Embedded Internet

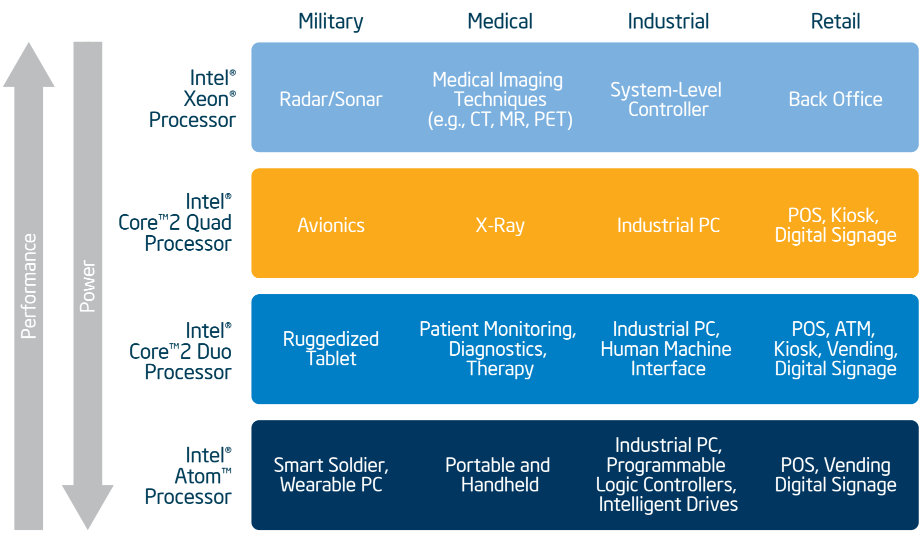

Figure 3

Intel® architecture delivers scalability for the Embedded Internet.

Intelligent Connected Devices

The explosion in the number of intelligent connected embedded devices will rely on the ability of the Internet ecosystem to generate increased revenue from new products and services, and improve existing products, processes and services. The availability of these devices will present service providers with new opportunities to deploy innovative Internet-based services across a broad range of previously untapped market segments.

For example, consumers are looking for convenient ways to more effectively and conveniently manage and monitor home systems and reduce utility costs. This presents an opportunity for service providers to market premise service gateways, which link home networks to electrical, water and gas meters, home heating, ventilation and air conditioning (HVAC) systems, fire and security systems and providers of entertainment and media services.

In the retail industry, new business models will create a significant up-tick in the number of connected devices, networks and intelligent devices, such as intelligent kiosks with powerful graphical human-machine interfaces (HMIs), to enable new retail applications and services. As the demand for new services grows, we will see the emergence of converged application-ready service platforms designed to streamline development.

In addition to home automation, Intel now sees many other market segments in which intelligent, connected embedded devices will create similar opportunities for new services. Portable medical monitors, in-vehicle infotainment, digital signage and advanced retail kiosks are just a few examples.

CLOSE-UP: INTELLIGENT RETAIL

Retail stores provide an excellent illustration of how the use of intelligent connected embedded devices can enrich user experiences, provide service deployment opportunities and maximize sales revenue while reducing operating expenses.

For example, a shopper using an RFID-equipped loyalty card, personal cell phone, store-owned MID device or intelligent shopping cart will be exposed to sales promotions, product purchasing assistance, customized products and services by just entering the store. In short, the shopping environment and experience adapts to recognizing the customer and sensing his or her needs.

Retail businesses are also exploring new ways to reduce operating expenses through remote system diagnostics and maintenance over a network connection that avoids the cost of a truck roll or the intervention of an onsite technician. Kiosks and POS devices based on embedded Intel processors deliver performance/watt efficiency and advanced power management technology that can help reduce energy consumption.

Instead of keeping their systems running 24/7, Intel® Active Management Technology (Intel® AMT)[2] enables POS devices to power down when they are not being used. Power-stepping in these platforms can result in power savings as much as 70 percent.[3]

Technical Barriers and Solutions

Technical barriers must be addressed to create a truly global communications network that can support billions of new intelligent connected devices. Working through the challenges presented by the Embedded Internet, Intel is involved in all of the following key areas

Barrier: Limited Internet Address Space

The Internet protocol (IP) is the common denominator of the Embedded Internet, but the rapid increase in the number of connected devices will have a major impact on Internet address space. The industry now expects that IPv4 will exhaust the previously unallocated address space in the next several years.[4] Supporting this premise, as of early 2007, about 2.8 billion mobile phones were in use worldwide, and 1.6 million new ones entered into usage every day. Now, the number of mobile phones in use worldwide is more than 3.5 billion, according to The Digital Economy Fact Book.

Solution: IPv6

The next evolution of the protocol, IPv6, vastly expands the available address space and can help support proliferation of broadband, connected mobile devices and sensor networks, as well as the development of new types of services.

Barrier: Proprietary Network Technologies

Proprietary technologies, like custom busses and non-standard application programming interfaces (APIs), limit interoperability.

Such approaches hinder component reuse and can drive the need for protocol translation and product specific software, which add to the complexity and cost of developing new devices.

Solution: Open Standards

Open standards enable faster innovation by removing proprietary barriers to product development. See the sidebar, "IP as the Common Transport Protocol for Embedded", for more details.

Barrier: Increasing Infrastructure Burden

As the edge of the network moves beyond the phone and PC to billions of connected embedded devices and sensors, the network infrastructure must support a wider spectrum of network traffic types, ranging from video to billions of RFID transactions.

Solution: Modular Telecom Infrastructure

Intel's latest generation of multi-core processors provides dramatic increases in performance per watt, enabling blade servers and carrier-grade rack mount servers to handle increases in data complexity and traffic volume within the thermal footprint of existing datacenters.

Barrier: Energy Cost

Power consumption is a major factor in connected intelligent digital signage and other applications.

Solution: Power-Efficient Performance

Intel's leading embedded processors and chipsets provide robust processing performance in embedded applications with thermal design power of less than 5 watts.[5] Intel embedded processors, from Intel Xeon processors in telecom equipment to Intel Atom processors in digital signs, are designed with advanced power states so devices only draw power when they are actually in use.

Barrier: Security and Privacy Requirements

The ability to connect, manage and ensure device security is a prerequisite for adoption of the Embedded Internet. Privacy-protection is key to the continuing deployment of embedded devices that recognize voices, faces, license plates, apparel and other personal identifiers.

Solution: Virtualization and Trusted Execution

Users of the Embedded Internet will carry a variety of digital tokens, such as RSA security keys, magnetic strips, smart cards, RFID enabled security badges and biometric devices. Protecting encrypted information is essential. Intel® Virtualization Technology[6] and Intel® Trusted Execution Technology[7] work together to help balance ease of use with essential privacy requirements in the Embedded Internet environment.

Barrier: Cost of Device Management

It's necessary to manage connected devices to ensure they're working properly. The rapid growth in the number of connected devices is likely to add to the complexity and cost of management.

Solution: Scalable, Remotely Manageable Devices

Intel® Active Management Technology allows IT to reduce the cost of asset management by performing a range of remote tasks, such as diagnostics and updating the software of connected devices.

Barrier: Disparate Networked Devices

Many networked devices will not work together without the adoption of an appropriate standards-based communications stack.

Solution: Standards-Based Communications Middleware

Open-source middleware designed for the Internet, such as Java*, JSON, XML, SOAP* and Python*, can provide developers with a standards-based framework for the unification of individual networked sensors and other embedded devices.

CLOSE-UP: IP AS THE COMMON TRANSPORT PROTOCOL FOR EMBEDDED

ZigBee (802.15.4) was created to address the industry need for a cost-effective, standards-based, networked wireless sensor solution that supports low-power consumption, security and reliability. It's used in market segments including home and building automation, smart energy metering, industrial automation and healthcare. However, the Zigbee protocol stack does not support IP, therefore 802.15.4 gateway solutions are required for IP translation.

Enabling an IP-based transport protocol solution, Compact Application Protocol (CAP) simplifies the deployment of large-scale sensor networks and applications. It reduces or eliminates protocol translation nodes, which in turn enables a wider audience to take advantage of the accumulated knowledge used in the definition of the ZigBee Application Profiles. This approach also frees the ZigBee Alliance to focus on the high-value applications for wireless sensor networks, such as energy management and industrial control.

Conclusion

Embedded computing is undergoing a transformation. Breakthroughs in computing performance per watt, in parallel with advances in wired and wireless broadband connectivity, will enable the development of billions of new intelligent embedded devices. As we work together to overcome the technical barriers, the Embedded Internet will create transformative opportunities as it becomes woven into the fabric of business and daily life.

For more information on Intel® technologies, visit www.intel.com/technology/advanced_comm.

Additional information about Intel® embedded products can be found at http://www.intel.com/products/embedded/index.htm.

[1] "The Computer for the 21st Century," Scientific American, September 1991

[2] Intel® Active Management Technology (Intel® AMT) requires the computer system to have an Intel® AMT-enabled chipset, network hardware and software, as well as connection with a power source and a corporate network connection. Setup requires configuration by the purchaser and may require scripting with the management console or further integration into existing security frameworks to enable certain functionality. It may also require modifications of implementation of new business processes. With regard to notebooks, Intel AMT may not be available or certain capabilities may be limited over a host OS-based VPN or when connecting wirelessly, on battery power, sleeping, hibernating or powered off. For more information, see www.intel.com/technology/platform-technology/intel-amt/.

[3] Langdoc, Scott. "Advanced CPUs: The Impact on TCO Evaluations of Retail Store IT Investments," *Global Retail Insights (An IDC Company)*, September 2008

[4] IPv4 Address Report, May 2009

[5] The TDP specification should be used to design the processor thermal solution. TDP is not the maximum theoretical power the processor can generate.

[6] Intel® Virtualization Technology requires a computer system with an enabled Intel® processor, BIOS, virtual machine monitor (VMM) and, for some uses, certain platform software enabled for it. Functionality, performance or other benefits will vary depending on hardware and software configurations and may require a BIOS update. Software applications may not be compatible with all operating systems. Please check with your application vendor.

[7] No computer system can provide absolute security under all conditions. Intel® Trusted Execution Technology requires a computer system with Intel® Virtualization Technology, an Intel TXT-enabled processor, chipset, BIOS, Authenticated Code Modules and an Intel TXT-compatible measured launched environment (MLE). The MLE could consist of a virtual machine monitor, an OS or an application. In addition, Intel TXT requires the system to contain a TPM v1.2, as defined by the Trusted Computing Group, and specific software for some uses. For more information, see www.intel.com/technology/security.

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