Executive summary

Today, a technological evolution is gathering momentum as intensive innovation connects billions of devices into intelligent, pervasive computing systems. This phenomenon is known as the Internet of Things, or IoT. An important element of the IoT is the capability of a system to examine the data generated from its processes and use those observations to suggest improvements to drive business improvement.

Data from IoT-connected elements provides finer-grained information on the operational health of the overall system and enables more frequent feedback into all kinds of business processes, automation processes and end-user experiences. This in turn allows us to tailor interactions with the world around us to better align with business objectives, and to reflect personal preferences for better customer experiences. This paper examines the IoT and looks at ways organizations can increase the scope and volume of data collection, understand what the data means and use it to create actionable information for business and process improvements.
In the IoT, powerful analytics turn massive data into new insights and opportunities.

Introduction
Data is the raw stock and currency of the Internet of Things. Smart systems generate and collect massive amounts of data. Powerful analytics turn this data into new information, uncover new opportunities, find new revenue streams for existing products and develop new processes to make business operations more efficient.

In examining the Internet of Things, five functional elements of a logical data cycle become apparent: acquisition, transport, aggregation, analysis and action (see figure). We can then overlay security, governance and management on this evolving landscape in order to describe paths to business action.

Data acquisition
Data acquisition encompasses the hardware — the smart devices — that capture data from interactions with the environment, with other machines, with humans or other living things and make it available for transmission over a network. Sensors are the nerve ends of the Internet of Things, and a growing assortment of devices are collecting data. Devices worn by joggers, embedded in automobiles and aircraft, mounted in railcars and mines, moving down assembly lines, attached to skyscrapers and in crates of food are all contributing observational data to smart systems.

Technical advances and diminishing collection costs are lessening constraints on the frequency, breadth of detail and depth of precision in data that sensors can capture, expanding the environments in which they can operate and lowering economic barriers to deploying very dense sensor arrays. The challenge in any IoT model is to contextually evaluate the type and quality of data, and then accurately distinguish between data relevant to local decision processing and data that is appropriate for transmission and consolidation.

Data transport
After collecting data from various sensors in the data acquisition stage, a smart system must then move the data over a network for aggregation and analysis. Wired and wireless networks are essential in connecting data-generating sources to the broader IoT ecosystem.

Five elements of the Internet of Things data cycle

- **Act:** Humans and systems learn from new information to take informed actions
- **Acquire:** Smart devices interact with the environment and themselves to acquire data
- **Analyze:** Advanced analytics create rich contextual information
- **Aggregate:** Intelligent storage collects and organizes data
- **Transport:** Self-configuring networks securely transport data
Some networks use nonstandard or proprietary network protocols, particularly in vertical markets where security and manageability are priorities.

WiFi wireless networks, Bluetooth and broadband cellular will play an important role as established open standards in mobile network protocols. WiFi is a well-defined wireless local area network protocol and a standard in mobile computing platforms. WiFi and Bluetooth are also effectively standard features in smartphones and tablets and are used by people the world over to keep their smartphones, tablets, PCs and home entertainment systems connected to the internet.

**Data aggregation**

A data aggregation solution depends on network support to collect data from sources and deliver aggregated output data to designated consumers. Data consumers can include databases, on-site services, analytics services, enterprise service buses, third-party cloud services and similar repositories. Maximizing the utility of the data resource requires a solution to have highly adaptive data integration and transformation capabilities.

Smart systems continuously produce and consume data, so it is important to understand what data is required at what time to satisfy operational needs. The following example illustrates this point (see figure). Modern hospitals increasingly have network-connected machinery, beds, facilities and so on. Each level of hospital operations requires different data, frequency, history and response times. Effective data aggregation and analysis functions must accurately process the appropriate data in context to deliver useful results.

**Analysis**

Big data and real-time analytics are central to differentiation and competitive advantage, and are an important source of revenue generation in IoT solutions. In such a data-intensive environment, effective analysis depends upon a system’s ability to ingest, process and learn from large and often continuous volumes of source data. Effective action varies with the type of business, but successful organizations apply what they learn from analytics to support more informed decision making, improve products or services, and optimize business operations.

The analytics function of an IoT system must be capable of automatically gathering source data, evaluating it and producing a decision based on standard predictive models. Further, it is essential that the system assimilate feedback from outcomes over time, to update those models as data and usage patterns evolve. Finally, the system must facilitate manual intervention in high-risk processes where full automation is not appropriate.

<table>
<thead>
<tr>
<th>Data type</th>
<th>Hospital room</th>
<th>Hospital operations</th>
<th>Hospital networks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose</td>
<td>Patient monitoring telemetry</td>
<td>Machine maintenance, asset inventory</td>
<td>Electronic medical records, patient data statistics</td>
</tr>
<tr>
<td>Sensor deployment</td>
<td>&gt;50 sensors</td>
<td>&gt;100,000 sensors</td>
<td>Millions of sensors</td>
</tr>
<tr>
<td>Data frequency</td>
<td>50 milliseconds</td>
<td>30 seconds</td>
<td>Daily</td>
</tr>
</tbody>
</table>

*Data aggregation requirements in a hospital setting*
Action
Better information to make more accurate and faster decisions is the fundamental motivation for deploying IoT technologies. Industries as diverse as healthcare, mining, utilities and agriculture recognize the potential to improve products and services, reduce costs and better manage processes by enriching operation-specific data from smart devices with contextual data from the environment to identify and predict patterns that result in specific outcomes, such as component failure.

Information and analytics to support rapid, data-driven decisions lay the foundation for more complex, system-initiated actions in process optimization and operational automation. Systems can assimilate data from the environment and learn to improve their own performance. Autonomous systems such as automotive collision avoidance systems, self-driving vehicles and unmanned aerial vehicles demand voluminous sensor inputs, real-time data analysis and multivariate, localized decision making in every second of operation.

The new tools of the IoT can rapidly combine a depth of information and unbiased analysis to guide better human and machine-based decisions. The potential for both quantitative and qualitative improvement in a broad spectrum of endeavors is the real power and promise of smart systems and the Internet of Things.

Security, privacy and manageability
Policy matters of data security, custodianship and access all figure prominently in the IoT. Key aspects of IoT security are similar to traditional IT:

Authentication: Is data coming from a valid sensor? Spoofing could be a huge problem in the IoT as well as reverse spoofing: How does a sensor know that data coming to it is from a valid source? Sending sensors spoofed instructions could do a lot of damage.

Authorization: As IoT complexity grows, a single sensor will surely send data to multiple consumers. Systems must be capable of enforcing authorization policies to ensure a sensor sends only where approved. Conversely, instructions...
to a sensor must assure the receiving device that the sender is authorized to issue the instructions.

**Data protection**: Protecting data in transit and at rest is essential. Physical security of sensors is not always possible, so sensors must be capable of encrypting the data they collect, in case someone gains physical access (that is, steals it). Encryption during transit is critical as well, but some sensors may not be extensible to add custom code to enhance security. Network protocols must include encryption, especially wireless protocols.

Management requirements are analogous in principle to traditional IT but with the challenge of executing management functions on remote sensors. Aspects of management include:

**Asset management**: Discovery of sensors will be a problem that is orders of magnitude more serious than in traditional IT. Device lifecycles will vary greatly, from embedded sensors that last for 10+ years to throwaway sensors that last a few weeks. The sheer number of sensors will preclude manual asset management.

**Configuration management**: IoT sensor management should be a fraction of that required for an IT end-user device, but again, having large numbers of these sensors creates a formidable task, complicated by a lack of standards in the short term.

**Performance and availability management**: Availability monitoring of sensors closely aligns with asset management and is critical for ensuring continuity of coverage across endpoints. Performance management is a small concern at the individual sensor, but has significant implications for the upstream transport, aggregation and analysis elements of a solution. The volume of data moving through the IoT pushes boundaries well beyond traditional IT management experience.

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**IoT cases in point**

Dell’s existing IT assets are in most respects a close fit to pervasive computing system uses. To accommodate anticipated data volumes, numbers of devices and varied operating conditions in this new domain, Dell continues to evolve and extend its asset capabilities.

**Telemedicine provider gains global scale overnight**

**Business need**: Telemedicine provider Health Net Connect sought a global technology partner with extensive healthcare IoT experience to help it scale quickly to meet exploding demand.

**Solution**: Total Dell OEM solution featuring managed fulfillment and support services.

**Benefits**:
- Gained global scale virtually overnight
- Increased capacity to meet demands of large customers
- Reduced time-to-market by months, if not years

**Dairy farming in India goes from cows to cloud with technology**

**Business need**: Chitala Dairy wanted a high-speed, highly available network that could support a massive growth in operations and the automation of its milk production process.

**Solution**: Dell virtualized platform and upgraded infrastructure.

**Benefits**:
- Innovative research and development driven by data captured at every level
- Milk production that achieves efficiencies through network virtualization
- Animal management that improves with increased access to information
Dell believes the Internet of Things is at a tipping point where innovation and falling costs are enabling organizations to begin preparing for the future now (see figure). The Internet of Things is a natural evolution in using technology convergence to enable more devices and elements to be connected to the internet. It is collections of objects, each incorporating embedded sensors or actuators and capable of machine-to-machine (M2M) communication over the internet individually or as systems. The IoT is based on core elements such as computers, networks, sensors, storage and application software. It is the advances in these elements, and new technologies tying them all together, that have opened the door to new uses and capabilities.

Costs of sensors, embedded systems and devices continue to fall because of innovation, competitive pressures, expanding global markets and economies of scale. For these reasons, the use of sensors is expected to grow substantially over the next six years.

There is a wider range of connectivity protocols as multiple standards-based wireless technologies drive low-cost wireless connectivity options, and new protocols make it possible to connect trillions of physical objects to the internet. Plus, there is the ubiquity of mobile devices. A billion mobile subscribers were added in the last few years, providing the opportunity to connect to, gather information from and communicate with more people than ever before.

The rise of cloud computing means your IT infrastructure can scale as fast as your data does as new sources of data are added to your network. High performance and cloud computing, combined with powerful new tools for data analysis, are creating new ways of using and monetizing the high volume of data that can be collected. Advances in familiar technologies, tied together with new software and applications, provide the fundamental building blocks for achieving the promise of the Internet of Things. Because you have some of this technology already, you may be more prepared for IoT initiatives than you think.
Dell is one of the few tier 1 information technology suppliers with assets in each of the critical categories of an IoT solution, including security, data acquisition, transport, aggregation, analytics and deployment services. We offer the following pointers for our clients who are considering IoT.

**Start with clarity**
Dell advises clients to identify realistic use cases, develop partnerships between IT and the business to leverage organization-wide expertise, and build outcomes-focused strategic plans that start small and grow based on real-world success.

- Clarify business outcomes and ROI
- Capitalize on IT and business expertise
- Start with what you have

**Architect for your specific needs**
Our open approach helps ensure your IoT solution meets your unique needs without imposing our view, provides robust analytics for insight-driven action, and allows you to scale from pilot to production quickly and cost-effectively.

- Build on your terms
- Unleash the power of analytics
- Scale performance

**Secure everything**
Dell’s end-to-end, connected security solutions help ensure your data is secure and private from endpoint devices to your data center to the cloud, and that you are compliant with ever-changing regulatory requirements.

- Ensure security from device to data center to cloud
- Protect data wherever it goes
- Secure data for compliance

By taking a practical, outcome-oriented approach and building on the technology investments you’ve already made, Dell can help you deliver on the promise of the Internet of Things today. Bring your ideas about how the IoT can add value for your organization and your customers — and we’ll help turn these ideas into reality.

**For more information**
To learn more about Dell IoT capabilities and how they can help your organization, contact your Dell sales representative or visit: Dell.com/oem

Organizations have some of the building blocks already, and may be more prepared for IoT than they think.
About Dell Software

Dell Software helps customers unlock greater potential through the power of technology—delivering scalable, affordable and simple-to-use solutions that simplify IT and mitigate risk. The Dell Software portfolio addresses five key areas of customer needs: data center and cloud management, information management, mobile workforce management, security and data protection. This software, when combined with Dell hardware and services, drives unmatched efficiency and productivity to accelerate business results. www.dellsoftware.com

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