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White Paper

Unlocking the Value of the Internet of Things (IoT) – A Platform Approach

About the Author(s)

Prateep Misra

Research Area Manager, TCS Innovation Labs

Prateep leads the development of platforms for Internet of Things applications. He has over 21 years' experience in the IT Industry in areas such as software development, research, technology consulting, and software quality assurance. His current focus areas include Machine-to-Machine (M2M) communication, cloud computing, large scale and real-time analytics platforms, IT Infrastructure architecture and design, and storage. Prateep was responsible for the design of IT infrastructure for a major SaaS product from TCS. He holds a BTech in Instrumentation Engineering and an MTech in Electrical Engineering, both from the Indian Institute of Technology, Kharagpur.

Arpan Pal

Head, TCS Innovation Labs - Kolkata

Arpan is a part of the Systems Research Council of TCS that focuses on cyber-physical systems. He has more than 21 years of experience in the areas of signal processing, communication, and real-time embedded systems. His current research interests include sensing and analytics based on mobile phones and cameras, physiological sensing, M2M communications, distributed computing, and semantic analytics for IoT based applications. He has been published in several journals, and has contributed to conferences and books. He has also filed for more than 45 patents, five of which have been granted so far. Arpan is a PhD from Aalborg University, Denmark and an MTech from the Indian Institute of Technology, Kharagpur.

Balamuralidhar P

Head, TCS Innovation Labs - Bangalore

At TCS, Bala oversees several research programs including Power Prism – smart meter Informatics, tele-augmented reality, vehicular telematics, aerial sensing/imaging, and searchable encryption/cryptography. His current interests include different aspects of cyber-physical systems, sensor informatics, and networked embedded systems. Bala has 25 years of research and development experience in signal processing, wireless communications and cyber physical systems. He has had over 60 articles published in various international journals and conferences, and over 25 patent applications. He is an MTech from IIT Kanpur and a PhD from Aalborg University, Denmark.

About the Author(s)

Sandeep Saxena

Lead Innovation Evangelist

Sandeep Saxena is responsible for proliferation and application of research work from TCS Innovation Labs. He conceptualizes solutions for each domain based on the research assets/findings from the labs. Sandeep also heads the go-to-market strategy for the solutions of partners in TCS' Co-Innovation Network (COIN). He has worked in various roles in the Application Development and Maintenance (ADM) space encompassing development, support, and project management. He has been in TCS for nearly two decades. Sandeep is a BE and also has an MSc in Economics from BITS, Pilani.

Sripriya R

Innovation Evangelist

Sripriya works at proliferating TCS innovations. She has around two decades of IT experience spanning software design, development, projects, programs, delivery assurance, and process management. She has been involved in defining the go-to-market strategy of TCS' research in IoT. She has a BE and an MBA in Business Finance, and has many certifications to her credit.

The Internet of Things (IoT) bridges the cyber and the physical worlds. The resulting 'cyber-physical systems' are poised to disrupt many businesses and bring computation seamlessly into our everyday lives. However, today the IoT landscape looks fragmented, with disparate devices, information, and platforms from a range of vendors. This threatens to lock down the realization of value from the IoT. Interoperability holds the key.

While there are attempts to develop protocols and standards, we believe that a central piece is a versatile Business to Business (B2B) sensor cloud platform that enables sensor data management as well as application building. This paper demonstrates the need for such a platform, and how organizations can use it to offer new services or improve their operations. The paper highlights the issues that businesses might face in deploying IoT applications. It also points the way to future areas of research related to cyber-physical systems.

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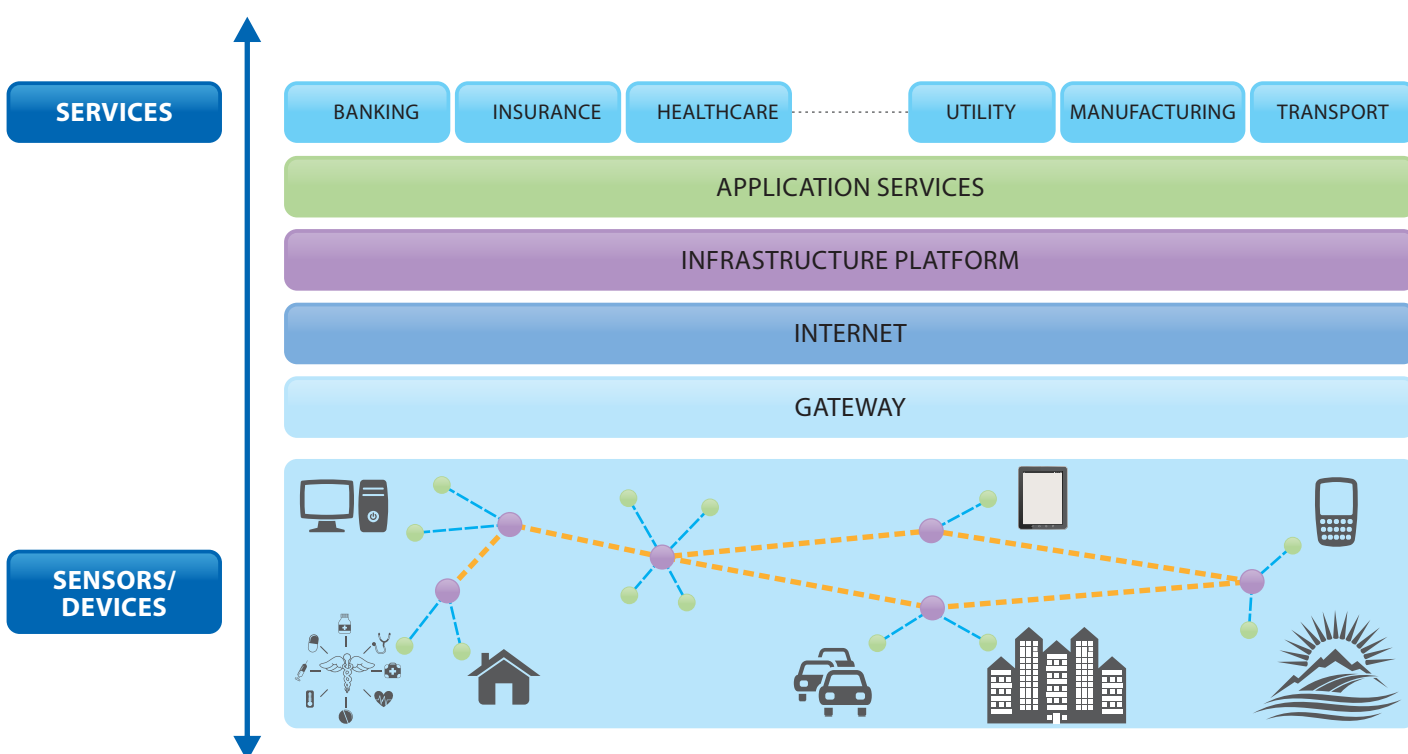
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1. Introduction

The Internet has been in existence for over forty years and the term 'Internet of Things' has been in use since the large scale adoption of RFID began a decade ago. So what is creating this new excitement about IoT? There are several factors. Today you have low cost but highly capable sensors, and advances in wired and wireless communication technology and network protocols that permit you to better connect sensors to the Internet. You have an array of tools, platforms, and analysis techniques that can process large amounts of sensor data and present meaningful insights. You can send data and receive insights through various devices such as your mobile phone, a tablet on your fridge, your car, or your computer. A close connection between things and humans, the cyber world and the physical world, has thus been established via sensors and devices. And that is why the potential for transformation is immense. Every industry will create new business models and offer new services to customers with the Internet of Things.

As depicted in Figure 1, several layers of technology help IoT drive transformations to the business.

Currently, IoT services are largely provided by device manufacturers. However, businesses need to engage with different devices and applications. How can such complexity be handled? We believe that a strong backbone that enables many functions is crucial to the delivery of IoT services. If your company wants to offer sensor based services, such as healthcare monitoring, or help your transport and logistics department trace vehicles or packages, you need a platform that allows **device monitoring, application development, and data management**. If there are value added services – such as analytics - on top of these, that would be a boon.



2. Device Management

An IoT platform should be able to let you plug in different devices and manage them remotely. Whether you are tracking a valuable asset on your shop floor, a wearable healthcare device, or a vehicle, you will need to configure the device and run firmware upgrades. You should also be able to work with the various software applications that relate to the device. You should be able to ensure device security and access to stakeholders. The platform must also permit you to monitor the device's connectivity and health, and run reports.

From a functional standpoint, data collection from IoT devices is extremely important. Data from the device may be collected or queried periodically, on-demand, on a scheduled basis or based on 'events'.

3. Application Management

Your business may have a number of IoT related applications, and you may also invite third parties to host apps. For application and data management, you need features that allow effective user management and resource provisioning, application life cycle management, provision for application modeling, and code generation.

4. Sensor Data Acquisition and Management

The core of your IoT application is sensor data. A platform's APIs should allow sensors, devices, gateways, proxies, and other kinds of clients to register sensors in the system and then insert sensor observations. The platform must be highly scalable since the number and type of sensors you may use and the observation capture rate may become very large over a period of time.

You may be running a number of applications related to your sensor based devices. It is important to have access to your data and to be able to manage your application database on the platform.

Once you have a bunch of apps running on the platform, huge volumes of data start flowing in. To realize the potential of an IoT platform you need an analytics engine to mine the data and offer insights. Analytics could include everything from traditional Business Intelligence (BI) to data mining, machine learning, statistical processing, predictive analytics, and time series analysis on stored sensor data. Real-time analytics on sensor streams include rule based processing, complex event processing, pattern detection, correlation, and more.

You should be able to offer insights to end-users in the form of rich visualization. Apart from standard graphs, bars, and charts, sensor data may be overlaid on top of maps or presented in gadgets or infographics. Visualization services may be provided via GUI based tools or APIs, or both.

5. The Application of IoT in Different Industries

The Internet of Things will enable organizations in every industry to offer new services or otherwise change their business models. Table 1 provides a glimpse of the new business models that 'cyber-physical systems' can enable in various industries.

Industry	Solution or Service	Sensors / Devices	Analytics	Interface	Outcome
Utilities (energy, water, gas)	<ul style="list-style-type: none"> Real-time collection of usage data Demand-supply prediction Load balancing Dynamic tariff generation 	<ul style="list-style-type: none"> Energy, water, or gas meters 	<ul style="list-style-type: none"> Historical usage analysis, usage prediction, demand-supply prediction 	<ul style="list-style-type: none"> Can be accessed on any internet connected device 	<ul style="list-style-type: none"> Consumers connected to these smart networks have seen significant cost and resource savings.^[1]
Manufacturing	<ul style="list-style-type: none"> Remote monitoring and diagnostics Production line automation Equipment handling and diagnostics through sensors located on the production floor Remote expert diagnostics in case of failures 	<ul style="list-style-type: none"> Supervisory control and data acquisition (SCADA) systems / Programmable Logic Controllers (PLCs) Controllers or gateway Cameras IoT devices mounted on asset IoT devices embedded in machines 	<ul style="list-style-type: none"> Anomaly detection in equipment usage and functionin Predictive maintenance Automatic quality monitoring in production line 	<ul style="list-style-type: none"> Mainly on central consoles Can connect to experts on their mobile terminals for remote consultation 	<ul style="list-style-type: none"> Reduced field support costs, lower breakdowns, improved operational efficienc Optimal scheduling of production lines Anomaly detection and emission detectio Improved quality and lower energy costs
Healthcare	<ul style="list-style-type: none"> Remote expert doctor consultation/ monitoring Chronic disease management Elderly care Wellness and fitness programs 	<ul style="list-style-type: none"> Wearable and personal medical devices Mobile phones 	<ul style="list-style-type: none"> Anomaly detection in recorded medical data Historical correlation 	<ul style="list-style-type: none"> Remote tele-consultation on medical super-specialist mobile terminals with the aid of clinical decision support systems 	<ul style="list-style-type: none"> Lower cost of care Improved patient outcomes Real-time disease management Improved quality of life for patients

[1] Phys.org, 'Test of building smart sensors yields big energy savings', April 2011, <http://phys.org/news/2011-04-smart-sensors-yields-big-energy.html>

IEEE Xplore, 'Smart Personal Sensor Network Control for Energy Saving in DC Grid Powered LED Lighting System', May 2013, <http://ieeexplore.ieee.org/xpl/articleDetails.jsp?reload=true&arnumber=6378420>

Industry	Solution or Service	Sensors / Devices	Analytics	Interface	Outcome
Insurance	<ul style="list-style-type: none"> ■ Collection of user data (like condition of home devices for home insurance, driving habits for car insurance) ■ Prediction of property damage ■ Remote inspection and assessment of damage and accidents 	<ul style="list-style-type: none"> ■ Sensors that depict the condition/ usage of the insured entity 	<ul style="list-style-type: none"> ■ Usage pattern detection ■ Anomaly detection ■ Automated assessments 	<ul style="list-style-type: none"> ■ Mobile apps - value-added usage based auto insurance applications, that calculate premiums based on driver behavior and usage 	<ul style="list-style-type: none"> ■ Creation of newer Insurance models such as dynamic premium pricing based on condition of property, premium pricing based on usage, and so on
Consumer goods and retail	<ul style="list-style-type: none"> ■ Accurate real-time knowledge of the consumer's context (presence, location, preferences, and so on) ■ Monitoring of supply chain inventory 	<ul style="list-style-type: none"> ■ Sensors that can capture end-user and inventory context: for example, RFID, location sensors, cameras, robots with sensors, specialized devices 	<ul style="list-style-type: none"> ■ Context-aided real-time user profiling ■ Analytics to extract context from raw sensor data ■ Entire gamut of supply chain analytics enhanced with real-time data 	<ul style="list-style-type: none"> ■ Suggestions and recommendations from user devices ■ Targeted advertisements on the end-user's mobile device 	<ul style="list-style-type: none"> ■ Creation of novel value-added applications for the consumer, like alerts on expiry dates, avatars to check products virtually, and so on ■ Targeted advertising
Transportation	<ul style="list-style-type: none"> ■ Real-time vehicle tracking and optimization for logistics and public transportation systems ■ Asset management and tracking 	<ul style="list-style-type: none"> ■ On-board vehicle gateway devices ■ RFID tags ■ Sensors 	<ul style="list-style-type: none"> ■ Visualization, prediction, optimization, and decision support systems for associated transportation systems 	<ul style="list-style-type: none"> ■ Real-time alerts to drivers/ operators ■ Dashboards / control panels in command and control centers ■ Public displays / signage ■ Web based queries and reports 	<ul style="list-style-type: none"> ■ Improved service levels ■ Lower costs and lower carbon footprint

Table 1: IoT Applications – Examples for Different Industries

6. Technology Challenges in IoT

As you gear up for launching sensor based services, there are still some practical challenges you may encounter.

- **Device management:** The number of sensors, gateways and devices will be extremely large and they are going to be spread over large geographical areas – often in remote, inaccessible and/or private locations. Ensuring that devices are completely automated and remotely manageable is a challenge.
- **Device diversity and interoperability:** Take the example of a power network in a city, which is sensor enabled, and needs to be monitored continuously in near real-time. The generation, transmission, and distribution functions in such a complex network require different types of sensor devices from different vendors. As many vendors do not support any standards in their products, there are sure to be interoperability issues.
- **Integration of data from multiple sources:** As you deploy an IoT application, you will get streams of data from different sources such as sensors, contextual data from mobile device information, and social network feeds and other web resources. It is important to note that the semantics of the data must be part of the data itself and not locked up within the application logic in different application silos.
- **Scale, data volume, and performance:** Prepare your business to manage the scale, data volume, and velocity of IoT applications. As the number of users and devices scale, so will the amount of data that needs to be ingested, stored, and analyzed. You will have a Big Data problem on your hands, and standard architectures and platforms may be inadequate. Also, where stringent real-time performance is required, network and application level latencies may be a problem.
- **Flexibility and evolution of applications:** You will witness sensors and devices evolving with new and improved capabilities. This will result in creation of new analytics techniques and algorithms, and new use cases and business models. You will need to quickly develop apps with minimal effort. You will need ecosystems and platforms that enable and sustain this.
- **Data privacy:** A good bit of data collected from devices will be sensitive personal data that must be protected from unauthorized access and used only for the specific purpose for which the user has allowed that data to be collected. Users have to be provided with necessary tools that enable them to define the policies for sharing their personal data with authorized persons and applications.

Another challenge, though not a technological one, is that you will have to work with a number of stakeholders. IoT works in a complex ecosystem, and an end-to-end IoT application touches several technologies, engineering activities, and other entities. Your maturity as a collaborative player becomes significant, as you need to work with different types of entities and organizations such as silicon chipset vendors, embedded boards and device vendors, IoT platform providers, communication service providers, system integrators, app developers, industry alliances as well as niche technology companies and startups.

7. Research Directions

In this transformational technology, innovation never ceases. There are areas where research is underway at TCS Innovation Labs, to deal with challenges discussed in this paper. Specific areas of research include:

- Scalability in networking, storage and computation to handle exponential growth of data volume from sensors
- Security of the 'data-at-flight' and 'data-at-rest' without compromising on scalability
- Preservation of privacy of the user data and properly balancing between privacy and utility
- Interoperability among myriad sensor data sources (physical communication level, network level, data syntax level, and data semantics level)
- Rich analytics and visualization (generic, sensor-specific, and domain-specific) provided in real-time, as required

Some of the related research challenges are depicted in Figure 2.

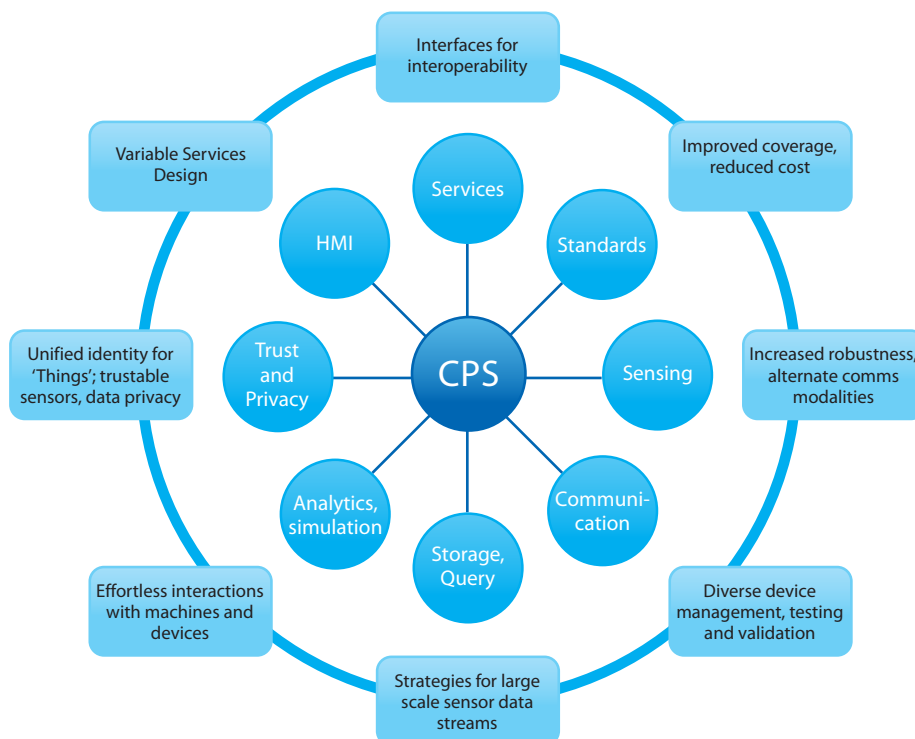


Figure 2: Major Research Challenges in IoT

8. Conclusion

Just as the internet has transformed businesses and lifestyles in the last twenty years, IoT will disrupt your organization's relationship with its stakeholders. While it is complex, and poses some risks and is still evolving, many pioneers have started adopting this technology. A technology agnostic platform that enables device management, application management, and sensor data management with analytics will jumpstart your engagement with cyber-physical systems. This can help you innovate new processes and initiatives to increase your organization's business performance, and create customer delight with new products and services.

For Further Readings:

- [1] *Journal of the Indian Institute of Science, A Multidisciplinary Reviews Journal* ISSN: 0970-4140 Coden-JIISAD VOL 93:3, 'Software Platforms for Internet of Things and M2M' by Balamurali P, Prateep Misra, Arpan Pal, Jul.-Sep. 2013
- [2] *Journal of ICT Standardization - Volume 1, No.2, 'Interoperation among IoT standards'* by Soma Bandyopadhyay P Balamuralidhar and Arpan Pal, August 2013.
- [3] *Perspectives, Volume 4, 'What the Future Holds - Beyond Mobility: Everywhere and Every Thing'* by K Ananth Krishnan, 2011
<http://sites.tcs.com/insights/perspectives/enterprise-mobility-telecommunications-telecom-technology-evolution>
- [4] *Perspectives, Volume 4, 'Mobile Telecommunications: Telecom Technology Evolution'* by Arpan Pal, P Balamuralidhar, Deepak Swamy, Mohammad Shahul Hameed, 2011,
<http://sites.tcs.com/insights/perspectives/enterprise-mobility-telecommunications-telecom-technology-evolution>

About Research

Research-led Business Innovation: TCS Corporate Technology Office governs formal research and innovation in the company. We have several disruptive innovations to our credit and we set up our first research lab in 1981 when the IT industry in India was just taking shape. We adopted Model Driven Development and created tools sets for each phase of the application development lifecycle. Today, TCS research is focused on Software, Applications and Systems exploration. Our Research and Innovation teams, through a global network of TCS Innovation Labs, work across domains and new technologies to deliver a range of solution frameworks to help your business to optimize, analyze, digitize, de-risk and sustain.

In the true spirit of collaboration and open innovation, we have created a Co-Innovation Network (TCS COIN™). This connects to several entities in the innovation ecosystem such as emerging technology companies, venture funds, academic research, strategic partners and key customers. We co-innovate with them, capitalizing on the strengths of each, to the benefit of all.

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