Abstract—The last few years have seen two key trends maturing in the industry: IoT and Big Data. These trends build on more than a decade of research in both academia and industry. As the cost of instrumentation and microprocessor chips has declined, it is now possible to monitor the environment on a widening scale. The cost decline is matched by cloud computing (exposed as web services) that provides infrastructure for storage and processing. Furthermore, on top of cloud, advances in big data tools/techniques provide a platform to analyze and understand the massive amount of data. But data generated from IoT is expected not only to be Big (volume) but also Fast (velocity). Data analysis and machine learning will play a key role in unlocking the value generated by IoT data. The Internet of Things (IoT) can be thought of in terms of connecting and combining the above mentioned elements. Combination of all these elements at various levels (e.g., physical objects, cloud service, mobile with rich user interfaces, analytics) will allow access and analysis of an enormous amount of fast data, which could be used to improve efficiency and performance of the whole enterprise. Moreover, it opens the possibilities of developing IoT applications in novel scenarios such as smart metering, smart electric car recharge stations, retail & logistics, and so on.

An important challenge that needs to be addressed is to enable the rapid development of IoT applications. Similar challenges have already been addressed in the closely related fields of Wireless Sensor and Actuator Networks (WSANs) and Pervasive/Ubiquitous computing. While the main challenge in the former is largely limited to similar nodes, the primary concern in the latter largely has been the heterogeneity of physical objects. The upcoming field of IoT will include both WSANs as well as heterogeneous physical objects, in addition to this it brings heterogeneity at various levels (e.g., physical objects, cloud service, smart phones with rich user interfaces, analytics) will allow access and analysis of an enormous amount of fast data, which could be used to improve efficiency and performance of the whole enterprise. Moreover, it opens the possibilities of developing IoT applications in novel scenarios such as smart metering, smart electric car recharge stations, retail & logistics, and so on.

Keywords—Internet of Things, Programming frameworks, Cloud Computing, Big Data, Data analytics

I. TUTORIAL PURPOSE

The aim of this tutorial is to bring together the software engineering, Internet of Things, cloud computing, data engineering communities. It will provide a discussion forum to bring together researchers from diverse research areas concerning all aspects of developing an ecosystem for bringing the next revolution via Internet of Things.

II. TARGET AUDIENCE

The tutorial is aimed at those who want to understand the on-ground concerns in architecting and developing real-life IoT applications. As such it will cater to both beginners and those already working in IoT.

- The tutorial will start with an introduction aimed at setting a common context of IoT for all participants.
- For beginners in this area, the introduction will create an understanding of what IoT means, common terminology, business impact and later get into details of IoT application development. Case studies / demos will aid understanding.
- For those already working in IoT, the tutorial will serve as a refresher for key concepts and serve as a forum to understand the latest research from corporate R&D organizations.

III. OUTLINE

The tutorial will focus on three key elements of enterprise-grade IoT applications:

Software engineering for IoT applications.
- Domain model for IoT applications [1], [2].
- Techniques for rapid development of IoT applications: model-based development [3], macro-programming languages and compilers, node-centric programming, database approach, development methodologies for IoT [4], [5], programming frameworks [6].
- Cloud platforms for rapid IoT application development.
- Impact of IoT on Software Development-life cycle [7].

IoT architecture.
- Architecture considerations for IoT applications.
- Product selection at different layers of the architectures.
- Security considerations across the architecture.

Data engineering for IoT Applications.
Sensor data poses some unique challenges for machine learning: some algorithmic and some computational. Given the interdisciplinary background of researchers and practitioners at the conference, we will start with the basic concepts and introduce some of the most widely used techniques in analytics. Then we will cover the challenges of analyzing sensor data and some of the key approaches which can be used to learn optimally from the high volume, high velocity data which is typical in IoT deployments. We will use examples from real-life sensor data to demonstrate the application of sensor data analytics.

The tutorial will have four sessions:

- Introduction to enterprise-grade IoT applications and architectures (Praphul Chandra, Vikrant Kaulgud, Ashok Kumar, Pankesh Patel) - 30 minutes
- Architecting enterprise-grade IoT applications (Vikrant Kaulgud) - 45 minutes
- Rapid development of enterprise-grade IoT applications (Pankesh Patel) - 45 minutes
- Data Analytics platforms for IoT (Ashok Kumar and Praphul Chandra) - 45 minutes

The tutorial will wrap up with a focused discussion on specific learning of the audience and open questions.

IV. PRESENTERS

**Praphul Chandra.** He is a Senior Research Scientist at Hewlett Packard (Analytics) where he works on structured and semi-structured data analytics. Prior to this, he was the principal investigator of the CrowdCloud project at HP Labs, India which aimed to combine human and machine intelligence for creating scalable solutions for enterprises. Before joining HP, he worked at Texas Instruments where his primary focus was on VoIP, WLANs and power management in embedded systems. His research interests include game theory, machine learning and complex networks. He is the author of two books and several book chapters, papers and patents. He completed his B.Tech in Electronics Engineering from IIT-BHU, M.S. in Electrical Engineering from Columbia University, New York and is currently working on his PhD in Mechanism Design at IISc-Bangalore.

**Vikrant Kaulgud.** He is a Senior Principal, R&D at Accenture Technology Labs. Vikrant has experience of over 20 years that includes R&D, consulting, academics, and entrepreneurship. He is a hands-on technologist and loves to deliver vision to value innovation. His work so far has spanned several technology areas – software engineering, IoT, collaboration, P2P distributed systems, and wireless and mobile systems. Vikrant has published 30+ papers at key conferences like ICSE, ISSRE, WCRE, IEEE Services 2011 and ISEC. He has served on program committees of top-tier academic conferences and workshops and occasionally is reviewer for journals like IEEE Software. Currently Vikrant is working on rapid development of IoT applications. In this area, he is investigating model-based approaches to IoT application development, knowledge-based architecture definition, using cloud platforms for enterprise-grade IoT applications etc.

**Ashok Kumar.** He is Senior Data Scientist working with Hewlett Packard ES Analytics Data Labs. He has 10+ years of experience in diverse domains like telecom big data analytics, scientific computing and agile software product development. He holds master degree in computational engineering from Indian Institute of Technology, Bombay. Currently working on Artificial intelligence based next generation Analytics platform. He is also involved in providing analytical consultancy to top telecom clients and instrumental in developing intellectual property in diverse analytical domain. Prior to joining HP, he was part of a team which had developed one of world’s fastest commercial supercomputer (Tata’s eka, 2007 Top500 Supercomputer List).

**Pankesh Patel.** He is serving ABB Corporate Research-Bangalore, India as a Research Scientist. He focuses in building software development methodologies and tools to easily develop applications in the cross-section of software engineering, cyber-physical systems, and Internet of Things. With this research, he has published more than 15 research articles in prestigious events like MIDDLEWARE, S-CUBE, OOPSLA, ICSE, SCC, ICDCN, Journal of System and Software (JSS), and CRC press for book chapter as a first author. He regularly serves various academic events as PC and invited/keynote speaker. He obtained his Ph.D. from the University of Paris VI (UPMC) and INRIA (French National Institute for Research in Computer Science and Automation) Paris, France.

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REFERENCES


