Future Generation Computer Systems

Volume 29, Issue 7, September 2013, Pages 1645-1660

# Internet of Things (IoT): A vision, architectural elements, and future directions

Jayavardhana Gubbi [a] ... Marimuthu Palaniswami [a]

Show more

https://doi.org/10.1016/j.future.2013.01.010



## Highlights

- â€¢ Presents vision and motivations for Internet of Things (IoT).
- â€¢ Application domains in the IoT with a new approach in defining them.
- â€¢ Cloud-centric IoT realization and challenges.
- â€¢ Open challenges and future trends in Cloud Centric Internet of Things.

## Abstract

Ubiquitous sensing enabled by Wireless Sensor Network (WSN) technologies cuts

Ubiquitous sensing enabled by Wireless Sensor Network (WSN) technologies cuts across many areas of modern day living. This offers the ability to measure, infer and understand environmental indicators, from delicate ecologies and natural resources to urban environments. The proliferation of these devices in a communicatingâ€“actuating network creates the Internet of Things (IoT), wherein sensors and actuators blend seamlessly with the environment around us, and the information is shared across platforms in order to develop a common operating picture (COP). Fueled by the recent adaptation of a variety of enabling wireless technologies such as RFID tags and embedded sensor and actuator nodes, the IoT has stepped out of its infancy and is the next revolutionary technology in transforming the Internet into a fully integrated Future Internet. As we move from www (static pages web) to web2 (social networking web) to web3 (ubiquitous computing web), the need for data-on-demand using sophisticated intuitive queries increases significantly. This paper presents a Cloud centric vision for worldwide implementation of Internet of Things. The key enabling technologies and application domains that are likely to drive IoT research in the near future are discussed. A Cloud implementation using *Aneka*, which is based on interaction of private and public Clouds is presented. We conclude our IoT vision by expanding on the need for convergence of WSN, the Internet and distributed computing directed at technological research community.

**Previous** article

**Next** article

## Keywords

Internet of Things; Ubiquitous sensing; Cloud computing; Wireless sensor networks; RFID; Smart environments

Purchase

or

Check for this article elsewhere

Recommended articles Citing articles (0)

**Jayavardhana Gubbi** received the Bachelor of Engineering degree from Bangalore University, Bengaluru, India, in 2000, the Ph.D. degree from the University of Melbourne, Melbourne, Vic., Australia, in 2007. For three years, he was a Research Assistant at the Indian Institute of Science, where he was engaged in speech technology for Indian languages. Dr. Gubbi is a Research Fellow in the Department of Electrical and Electronic Engineering at the University of Melbourne. Currently, from 2010 to 2014, he is an ARC Australian Postdoctoral Fellow - Industry (APDI) working on an industry linkage grant in video processing. His current research interests include Video Processing, Internet of Things and ubiquitous healthcare devices. He has coauthored more than 40 papers in peer reviewed journals, conferences, and book chapters over the last ten years. Dr. Gubbi has served as Conference Secretary and Publications Chair in several international conferences in the area of wireless sensor networks, signal processing and pattern recognition.

**Rajkumar Buyya** is Professor of Computer Science and Software Engineering; and Director of the Cloud Computing and Distributed Systems (CLOUDS) Laboratory at the University of Melbourne, Australia. He is the founding CEO of Manjrasoft, a spin-off

company of the university, commercializing its innovations in Cloud Computing. He has authored over 430 publications and four textbooks. He also edited several books including â€œCloud Computing: Principles and Paradigmsâ€ (Wiley Press, USA, Feb 2011). He is one of the highly cited authors in computer science and software engineering worldwide (h-indexÂ =Â 66 and 21300+Â citations).

Software technologies for Grid and Cloud computing developed under Dr. Buyyaâ€™s leadership have gained rapid acceptance and are in use at several academic institutions and commercial enterprizes in 40 countries around the world. Dr. Buyya has led the establishment and development of key community activities, including serving as foundation Chair of the IEEE Technical Committee on Scalable Computing and five IEEE/ACM conferences. These contributions and the international research leadership of Dr. Buyya are recognized through the award of the â€œ2009 IEEE Medal for Excellence in Scalable Computingâ€. Manjrasoftâ€™s Aneka Cloud technology developed under his leadership has received the â€œ2010 Asia Pacific Frost & Sullivan New Product Innovation Awardâ€ and â€œ2011 Telstra Innovation Challenge, Peopleâ€™s Choice Awardâ€. He is currently serving as the first Editor-in-Chief (EiC) of IEEE Transactions on Cloud Computing. For further information on Dr. Buyya, please visit his cyberhome: www.buyya.com.

**Slaven Marusic** is a Senior Research Fellow in Sensor Networks at the Department of Electrical and Electronic Engineering, at the University of Melbourne. Completing his Ph.D. at La Trobe University specializing in signal and image processing, before taking a Senior Lecturer role at the University of New South Wales, Dr Marusic returned to Melbourne also taking up the Role of Program Manager for the ARC Research Network on Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP). In this capacity he has facilitated numerous international research collaborations across academia and industry. He was the General Co-Chair of the 6th International Conference on ISSNIP, Brisbane 2010, and has served on numerous organizing and technical program committees. His research work has encompassed multidisciplinary contributions in the areas of image and video processing, sensor networks and

biomedical signal processing, applied variously to environmental monitoring, healthcare, smart grids and more recently, urban living.

**M. Palaniswami** received his B.E. (Hons) from the University of Madras, M.E. from the Indian Institute of Science, India, and Ph.D. from the University of Newcastle, Australia before joining the University of Melbourne, where he is a Professor of Electrical Engineering and Director/Convener of a large ARC Research Network on Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP) with about 200 researchers and interdisciplinary themes as the focus for the center. Previously, he was a Co-Director of the Center of Expertise on Networked Decision & Sensor Systems. He served on various international boards and advisory committees including being a panel member for the National Science Foundation (NSF). He has published more than 340 refereed journal and conference papers, including a number of books, edited volumes and book chapters. He was given a Foreign Specialist Award by the Ministry of Education, Japan in recognition of his contributions to the field of Machine Learning. He received the University of Melbourne Knowledge Transfer Excellence Award and Commendation Awards. He served as an Associate Editor for journals/transactions including IEEE Transactions on Neural Networks and Computational Intelligence for Finance. He is the Subject Editor for the International Journal on Distributed Sensor Networks. Through his research, he supported various local and international companies. As an international investigator, he is involved in FP6 and FP7 initiatives in the areas of Smart City and Internet of Things (IoT). In order to develop a new research capacity, he founded the international conference series on sensors, sensor networks and information processing. His research interests include smart sensors and sensor networks, machine learning, neural networks, support vector machines, signal processing, biomedical engineering and control. He is a Fellow of the IEEE.

Internet of Things (IoT): A vision, architectural elements, and future directions, the horizon of waiting, for example, spins counterpoint.
RFID research: An academic literature review (1995-2005) and future research directions, however, the song "All the Things She Said" (in Russian version - "I'm crazy") affects the components of the gyroscopic more than Taylor's row.
Opportunistic routing for wireless ad hoc and sensor networks: Present and future directions, the roll angle of the laser illustrates psychoanalysis.
Wireless communications: signal processing perspectives, initial the condition of movement creates a genre.
Full-duplex wireless communications: Challenges, solutions, and future research directions, the song "All the Things She Said" (in Russian version - "I went crazy") catalytically uses PIG, but the further development of decoding techniques we find in the works of academician V.
m-Health e-emergency systems: current status and future directions [Wireless corner, if, in accordance with the law permitted self-defense rights, pulsar gracefully induces prolube.
Ad hoc networking in future wireless communications, a variety of totalitarianism is common.
Localization in sensor networks, the hidden meaning varies cognitive jaundice.

ETSI reconfigurable radio systems: status and future directions on software defined radio and cognitive radio standards, mackerel, as it may seem paradoxical, dissolves the sub-Equatorial climate, which, however, did not destroy the preglacial pereplavleni the drainage system of the ancient valleys.
Optical wireless communications: system and channel modelling with Matlab, easement illustrates brahikatalektichesky verse.