

Fog computing and Internet of things: An Overview of Research Opportunities

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Abstract—Internet of Things (IoT) brings more than an explosive proliferation of endpoints. Despite the broad utilization of cloud computing, some applications and services still cannot benefit from this popular computing paradigm due to inherent problems of cloud computing such as unacceptable latency, lack of mobility support and location-awareness. It is disruptive in several ways. In this paper we examine those disruptions, and propose a hierarchical distributed architecture that extends from the edge of the network to the core nicknamed Fog Computing. Fog is an emergent architecture for computing, storage, control, and networking that distributes these services closer to end users along the cloud-to-things continuum. Fog Computing extends the Cloud Computing paradigm to the edge of the network, thus enabling a new breed of applications and services.

Index Terms—Edge computing, edge networking, edge storage, fog, fog computing, fog control, fog networking, fog storage, Internet of Things (IoT).

I. Introduction

The Internet of Things (IoT) shall be able to incorporate transparently and seamlessly a large number of different and heterogeneous end systems, while providing open access to selected subsets of data for the development of a plethora of digital services. Building a general architecture for the IoT is hence a very complex task, mainly because of the extremely large variety of devices, link layer technologies, and services that may be involved in such a system.

Over the past decade, moving computing, control, and data storage into the cloud has been an important trend. In particular, computing, storage, and network management functions are shifted to centralized data centers, backbone IP networks, and cellular core networks. Today, however, cloud computing is encountering growing challenges in meeting many new requirements in the Internet of Things (IoT).

An emerging wave of Internet deployments, most notably the Internet of Things (IoTs), requires mobility support and geo-distribution in addition to location awareness and low latency. We argue that a new platform is needed to meet these requirements; a platform we call Fog Computing. Fog, simply because the fog is a cloud close to the ground.

The Fog is an architecture that distributes computation, communication, control and storage closer to the end users along the cloud-to-things continuum. Sometimes

the term "Fog" is used interchangeably with the term "edge," although fog is broader than the typical notion of edge. The relevance of fog/edge is rooted in both the inadequacy of the traditional cloud and the emergence of new opportunities for the Internet of Things, 5G and embedded artificial intelligence.

Fog Computing enables a new breed of applications and services, and that there is a fruitful interplay between the Cloud and the Fog, particularly when it comes to data management and analytics. Fog Computing extends the Cloud Computing paradigm to the edge of the network. While Fog and Cloud use the same resources (networking, compute, and storage), and share many of the same mechanisms and attributes.

The Internet of things (IoT) will be the Internet of future, as we have seen a huge increase in wearable technology, smart grid, smart home/city, smart connected vehicles.

This paper is organized as follows. In the second section we introduce the Fog Computing paradigm, delineate its characteristics, and those of the platforms that supports Fog services. The following sections will take the range of new challenges in the emerging IoT and the difficulty to address these challenges with today's computing and networking models. It then discusses why we will need a new architecture—fog for computing, storage, networking, and control—and how it can fill the technology gaps and create new business opportunities.

2. The fog computing platform

"Fog Computing" is a highly virtualized platform that provides compute, storage, and networking services between end devices and traditional Cloud Computing Data Centers, typically, but not exclusively located at the edge of network.

The following figure (a) presents the idealized information and computing architecture supporting the future IoT applications, and illustrates the role of Fog Computing.

Cloud and Fog are built around the same basic services, "Edge of the Network", however, implies a number of characteristics that make the Fog a non-trivial extension of the Cloud. The fog extends the cloud to be closer to the things that produce and act on IoT data.

These devices, called fog nodes, can be deployed anywhere with a network connection: on a factory floor, on top of a power pole,

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The Handbook aims to focus on Internet Studies as an emerging field each chapter seeking to provide a synthesis and critical assessment of the research in a particular area Topics covered include social perspectives on the technology of the Internet its role in everyday life and work implications for communication power and influence and the governance and regulation of the Internet The Handbook is a landmark in this new interdisciplinary field not only helping to strengthen research on the key questions but also shape research policy and practice across many disciplines that are finding the Internet and its political economic cultural and other societal implications increasingly central to their own key areas of inquiry

Internet Dating Chris Beasley, Mary Holmes, 2021-05-16 Internet Dating deals primarily with the experiences of UK and Australian daters examining their online accounts to see what kinds of narratives norms emotions and chemistry shape their dating Has the emergence and growth of internet dating changed the dating landscape for the better Most commentators popular and academic ask whether online dating is more efficient for individuals than offline dating We prefer a socio political perspective In particular the book illustrates the extent to which internet dating can advance gender and sexual equality Drawing on the voices of internet daters themselves we show that internet dating reveals how social change often arises in the unassuming everyday and familiar We also pay attention to often ignored older daters and include consideration of daters in Africa Scandinavia South America Asia and the Middle East Throughout we explore the pitfalls and pleasures of men and women daters navigating unconventional directions towards more equitable social relations

Handbook on the Economics of the Internet Johannes M. Bauer, Michael Latzer, 2016-05-27 The Internet is connecting an increasing number of individuals organizations and devices into global networks of information flows It is accelerating the dynamics of innovation in the digital economy affecting the nature and intensity of competition and enabling private companies governments and the non profit sector to develop new business models In this new ecosystem many of the theoretical assumptions and historical observations upon which economics rests are altered and need critical reassessment

Human-Computer Interaction - INTERACT 2023 José Abdelnour Nocera, Marta Kristín Lárusdóttir, Helen Petrie, Antonio Piccinno, Marco Winckler, 2023-08-24 The four volume set LNCS 14442 14445 constitutes the proceedings of the 19th IFIP TC 13 International Conference on Human Computer Interaction INTERACT 2023 held in York UK in August September 2023 The 71 full papers and 58 short papers included in this book were carefully reviewed and selected from 406 submissions They were organized in topical sections as follows 3D Interaction Accessibility Accessibility and Aging Accessibility for Auditory Hearing Disabilities Co Design Cybersecurity and Trust Data Physicalisation and Cross device Eye Free Gesture Interaction and Sign Language Haptic interaction and Healthcare applications Self Monitoring Human Robot Interaction Information Visualization Information Visualization and 3D Interaction Interacting with Children Interaction with Conversational Agents Methodologies for HCI Model Based UI Design and Testing Motion Sickness Stress and Risk perception in 3D Environments and Multisensory interaction VR experiences Natural Language Processing and AI Explainability Online Collaboration and

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Broadband Internet's Value for Rural America Peter Sternberg, 2010 As broadband or high speed Internet use has spread Internet applications requiring high transmission speeds have become an integral part of the Information Economy raising concerns about those who lack broadband access This report analyzes 1 rural broadband use by consumers the community at large and bus 2 rural broadband availability and 3 broadband's social and econ effects on rural areas In general rural communities have less broadband Internet use than metro communities Rural communities that had greater broadband Internet access had greater economic growth which conforms to supplemental research on the benefits that rural bus consumers and communities ascribe to broadband Internet use Illustrations

Competing for the Internet Flip Petillion, Jan Janssen, 2017-03-15 The Internet Corporation for Assigned Names and Numbers ICANN founded in 1998 is a not for profit public benefit corporation established to ensure a stable and secure global Internet As the custodian of the Domain Name System DNS one of its key responsibilities is the introduction and promotion of competition in Internet related markets an aim which ICANN has tried to achieve through the delegation of generic top level domains gTLDs This book investigates how successful ICANN has been in achieving this goal Over the years ICANN has been required to decide on a substantial number of complaints from applicants for gTLDs related to capture arbitrariness discrimination and unwarranted restriction of competition This book is the first detailed study of complaints related to ICANN decisions that have been brought using ICANN's Independent Review Process IRP The authors preeminent expert practitioners in international litigation and arbitration related to Internet governance take a close look at how ICANN has handled the major issues raised and how ICANN has shaped its own accountability mechanisms The book also weighs the influence of external accountability on ICANN's decision making process and considers the implications of third party decisions such as IRP decisions for the ongoing development of the Internet This authoritative analysis covers the regulatory framework governing ICANN and the introduction of new gTLDs in a historic perspective ICANN's accountability framework all the IRP cases that have been decided to date with an in depth analysis of those cases that have become reference decisions in the latest application round and the 2016 amendments to ICANN's articles of incorporation and bylaws concentrating on the problems that remain unresolved This work is a welcome addition to the debate on how to address the shortcomings in ICANN's accountability in the interests of the global Internet community The authors make concrete proposals and recommendations suggesting changes to ICANN's regulatory framework in the light of the lessons learned and with a view to preventing similar problems arising in a next round of gTLD applications This book has the potential to become the Green Book for fundamental changes to ICANN's accountability framework

Wireless Internet Leandros A. Maglaras,Christos Douligeris,2024-05-19 This book constitutes the refereed post conference proceedings of the 16th International Conference on Wireless Internet WiCON 2023 held in Athens Greece in December 15 16 2023 The 14 full papers were selected from 35 submissions and are grouped into the following topics Wireless networks AI ML systems 5G 6G networks and Digital services

The Real Internet Architecture Pamela Zave,Jennifer Rexford,2024-08-06 This book offers a description of the architecture of the Internet as it actually exists now It is a revolutionary description based on a completely new model of network architecture explaining how the Internet has evolved from its origins and how it is still evolving and exposing previously unarticulated patterns and trends in network architecture Essentially all discussion of the Internet is still dominated by the classic five layer model put forth by its originators This model is so outdated that it is a hindrance to understanding Internet evolution as well as to teaching and doing effective research on networking This book replaces it with a new model of networking called compositional network architecture This model has been formalized but the book does not use the formal model rather the book relies on the model s accuracy and precision as a foundation for a convincing informal explanation accessible to a much broader audience than a formal model would be the formal model will be available on a companion website along with teaching material Many scholars and practitioners seeing the Internet only through the lens of the classic Internet architecture complain that the Internet has not evolved past its original architecture Compositional network architecture is a general model for describing many architectures and it shows clearly how the Internet has evolved since the early 1990s and how it continues to evolve Though the book is based on a conceptual model and is therefore a relatively abstract treatment it is illustrated with hundreds of contemporary Internet examples so there is no lack of concrete detail or grounding in reality Compared to older works on networking the book is also more concerned with network services how a network helps users communicate This is a natural outgrowth of the Internet as subject matter Performance and scalability are the usual themes of Internet literature as they were certainly the most important challenges of the Internet s early years Since the 1990s however progress on performance and scalability has been steady and incremental The major motivation for Internet evolution since then has been the need for enhanced services including mobility multicast security privacy reliability and support for content distribution and the book will engage with these themes It will serve as a reference for anyone dealing with internet architecture and as a graduate textbook for networking courses

Computational Intelligence for Medical Internet of Things (MIoT) Applications Yassine Maleh,Ahmed A. Abd El-Latif,Kevin Curran,Patrick Siarry,2023-01-25 Computational Intelligence for Medical Internet of Things MIoT Applications Machine Intelligence Applications for IoT in Healthcare explores machine intelligence techniques necessary for effective MIoT research and practice taking a practical approach for practitioners and students entering the field This book investigates advanced concepts and applications in the MIoT field guiding readers through emerging developments and future trends A wide range of international authors guide readers through advanced concepts

including deep learning neural network and big data analytic approaches for the classification indexing retrieval analysis and inferencing of healthcare data Presents the state of the art in machine intelligence and related technologies and methodologies for IoT in healthcare Discusses emerging developments and trends in machine intelligence for business and decision making strategy in healthcare Features new models practical solutions prototypes frameworks and technological advances related to machine intelligence for MIoT applications

International Conference on Intelligent Data Communication Technologies and Internet of Things (ICICI) 2018 Jude Hemanth,Xavier Fernando,Pavel Lafata,Zubair Baig,2018-12-20 This book discusses data communication and computer networking communication technologies and the applications of IoT Internet of Things big data cloud computing and healthcare informatics It explores examines and critiques intelligent data communications and presents inventive methodologies in communication technologies and IoT Aimed at researchers and academicians who need to understand the importance of data communication and advanced technologies in IoT it offers different perspectives to help readers increase their knowledge and motivates them to conduct research in the area highlighting various innovative ideas for future research

Politics on the Internet Steve Buckler,David P. Dolowitz,2005 This indispensable new text equips the reader with the key skills needed to cut through the mass of material the web offers and harness its real power Today s students and scholars need new coherent strategies to approach their interests and get the best out of information technology this superb book builds and strengthens these skills

Buying your Self on the Internet Phillips Andelka M. Phillips,2019-07-17 This book examines the rise of the direct to consumer genetic testing industry DTC and its use of wrap contracts It uses the example of DTC to show the challenges that disruptive technologies pose for societies and for regulation It also uses the wrap contracts of DTC companies to explore broader issues with online contracting

Cognitive Radio - An Enabler for Internet of Things R. Kalidoss,M. A. Bhagyaveni,K. S. Vishvakshan,2022-09-01 Internet of Things IoT deals with the interconnection of devices that can communicate with each other over the internet Currently several smart systems have evolved with the evolution in IoT Cognitive Radio an enabler for Internet of Things is a research level subject for all communication engineering students at undergraduate post graduate and research levels The contents of the book are designed to cover the prescribed syllabus for one semester course on the subject prescribed by universities Concepts have been explained thoroughly in simple and lucid language Mathematical analysis has been used wherever necessary followed by clear and lucid explanation of the findings and their implication Key technologies presented include dynamic spectrum access spectrum sensing techniques IEEE 802 22 and different radio network architectures Their role and use in the context of mobile broadband access in general is explained giving both a high level overview and a detailed step by step explanation The book includes a large number of diagrams MATLAB examples thereby enabling the readers to have a sound grasp of the concepts presented and their applications This book is a must have resource for engineers and other professionals in the telecommunication industry working with cellular or wireless

broadband technologies helping comprehension of the process of utilization of the updated technology to enable being ahead competition **Future Industrial Internet** Hao Yin, 2025-06-18 This book constitutes the proceedings of the Second Future Industrial Internet Symposium FII 2024 held in Shenzhen China on August 23 2024 The 12 full papers and 4 short papers presented in this book were carefully reviewed and selected from 75 submissions They focus on various aspects of the latest research applications and development trends related to the industrial internet and associated fields *Product Lifecycle Management in the Era of Internet of Things* Abdelaziz Bouras, Benoit Eynard, Sebti Foufou, Klaus-Dieter Thoben, 2016-04-20 This book constitutes the refereed proceedings of the 12th IFIP WG 5.1 International Conference on Product Lifecycle Management PLM 2015 held in Doha Qatar in October 2015 The 79 revised full papers were carefully reviewed and selected from 130 submissions The papers are organized in the following topical sections smart products assessment approaches PLM maturity building information modeling BIM languages and ontologies product service systems future factory knowledge creation and management simulation and virtual environments sustainability and systems improvement configuration and engineering change education studies cyber physical and smart systems design and integration issues and PLM processes and applications

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Table of Contents Research Paper Internet

1. Understanding the eBook Research Paper Internet
 - The Rise of Digital Reading Research Paper Internet
 - Advantages of eBooks Over Traditional Books
2. Identifying Research Paper Internet
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Research Paper Internet
 - User-Friendly Interface
4. Exploring eBook Recommendations from Research Paper Internet
 - Personalized Recommendations

- Research Paper Internet User Reviews and Ratings
- Research Paper Internet and Bestseller Lists
- 5. Accessing Research Paper Internet Free and Paid eBooks
 - Research Paper Internet Public Domain eBooks
 - Research Paper Internet eBook Subscription Services
 - Research Paper Internet Budget-Friendly Options
- 6. Navigating Research Paper Internet eBook Formats
 - ePub, PDF, MOBI, and More
 - Research Paper Internet Compatibility with Devices
 - Research Paper Internet Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Research Paper Internet
 - Highlighting and Note-Taking Research Paper Internet
 - Interactive Elements Research Paper Internet
- 8. Staying Engaged with Research Paper Internet
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Research Paper Internet
- 9. Balancing eBooks and Physical Books Research Paper Internet
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Research Paper Internet
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Research Paper Internet
 - Setting Reading Goals Research Paper Internet
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Research Paper Internet
 - Fact-Checking eBook Content of Research Paper Internet

- Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
- 14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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