On the Integration of Cloud Computing and Internet of Things

FiCloud-2014, August 27 2014 – Barcelona, Spain
Alessio Botta, Walter de Donato, Valerio Persico, Antonio Pescapè
The CloudIoT Paradigm

Cloud Paradigm
- Everything as a Service (*aaS)
- Easy flexibility and scalability
- Pay-as-you-go model and reduced business risk

Internet of Things (IoT)
- Intelligent and self-configuring nodes
- Communicating-actuating network
- Enabler for ubiquitous and pervasive computing scenarios
The CloudIoT Paradigm: a Survey

Why?

- Many works merge Cloud and IoT paradigms
- Many works have surveyed Cloud and IoT separately
- To the best of our knowledge literature lacks a detailed analysis on the Integration of Cloud and IoT
Methodology of the Survey

Temporal Characterization of the Literature

Complementarity of Cloud and IoT

Application Scenarios

Main Platforms, Services, and Research Projects

Hot Topics, Open Issues, and Future Directions
Methodology of the Survey

Temporal Characterization of the Literature

Complementarity of Cloud and IoT

Application Scenarios

Main Platforms, Services, and Research Projects

Hot Topics, Open Issues, and Future Directions
Temporal Characterization of the Literature

- Research and Interest Trends about Cloud and IoT
- Source: Google Scholar
Methodology of the Survey

Temporal Characterization of the Literature

Complementarity of Cloud and IoT

Application Scenarios

Main Platforms, Services, and Research Projects

Hot Topics, Open Issues, and Future Directions
Complementarity of Cloud and IoT

Cloud

- Virtual Resources
- Ubiquitous
- Unlimited Resources
- Internet for Service Delivery

IoT

- Real world (everyday) Things
- Pervasive Things
- Poor Resources
- Internet as a Point of Convergence
The Need for Integration: Storage

IoT involves

- a large set of information sources
- a huge amount of non-structured/semi-structured (BIG) data
- the need for collecting, searching, accessing, sharing, visualizing this data

Cloud is the most convenient and effective solution to accomplish these tasks
The Need for Integration: Computation

- Things have typically very limited computational and energy resources
  - Limited resources do not allow on-site processing
  - In some cases aggregation nodes are needed

- Cloud enables
  - task-offloading and energy saving
  - scalable, real-time, sensor-centric applications
  - data-driven decisions
  - prediction algorithms
The Need for Integration: Communication

- IoT typically requires that devices communicate (through dedicated hardware)

- Cloud offers an effective and cheap solution
  - to connect, track, and manage
  - any thing from anywhere at any time
  - using customized portals and built-in apps
The (Positive) Effects of Integration

- New convergence scenario
  - New opportunities for data aggregation, integration, and sharing

- Analyses of unprecedented complexity

- Increased revenues and reduced risk
  - Data-driven decision making algorithms

- New capabilities and paradigms
  - Sensor as a Service (SenaaS)
  - Data as a Service (DaaS)
Methodology of the Survey

Temporal Characterization of the Literature

Complementarity of Cloud and IoT

Application Scenarios

Main Platforms, Services, and Research Projects

Hot Topics, Open Issues, and Future Directions
A wide set of applications is **made possible** or **significantly improved** by CloudIoT.
Application Scenarios

- A wide set of applications is made possible or significantly improved by CloudIoT.
CloudIoT and Healthcare

- Continuous and systematic innovation with IoT and multimedia technologies in ambient-assisted living and telemedicine

- CloudIoT as an enabler for cost-effective, efficient, timely, and ubiquitous medical services
  - Health information delivery
  - Managing healthcare sensor data efficiently
  - Reduced need for expertise in technology infrastructures through abstraction of technical details
CloudIoT and Videosurveillance

- Intelligent Videosurveillance is a tool of the greatest importance for several security related applications

- Requirements of storage
  - Centrally secured
  - Fault tolerant
  - Accessible on-demand
  - Accessible at high speed

- Requirements of processing
  - Video processing
  - Computer vision algorithms
  - Pattern recognition modules

- Cloud-based solution as an alternative to in-house self-contained approach
  - Storage, processing, deliver
CloudIoT and Smart City

- Ubiquitous connectivity and real-time applications for smart city

- Sensor platform
  - Heterogeneous sensing devices
  - Large-scale

- Cloud Architecture
  - Discovery, connection, and integration of things
  - Automatic management, analysis, and control

- Common middleware for future-oriented smart-city services
  - Collecting information from heterogeneous infrastructure
  - Exposing it in a uniform way
Methodology of the Survey

Temporal Characterization of the Literature
Complementarity of Cloud and IoT
Application Scenarios
Main Platforms, Services, and Research Projects
Hot Topics, Open Issues, and Future Directions
Platform and Services

Bridge the gap between Cloud and IoT

• Solve issues related to the heterogeneity of Things and Clouds
• Typically provide an API towards the applications

Different Approaches

• Ready to use platforms
• Platform aimed at creating a toolkit (e.g., to glue protocols for the things, the clouds or the applications)

Different Solutions

• Open Source and Commercial
• Working with Open Things or bound to Proprietary Things
(Examples of) Open Source Platforms

**IoTCloud**
- Aimed at integrating the things with backends for managing sensors
- Showcased with video sensors (IP-cameras) on FutureGrid Cloud testbed
- [http://sites.google.com/site/opensourceiotcloud/](http://sites.google.com/site/opensourceiotcloud/)

**OpenIoT**
- Financed by EU
- Aimed at providing a middleware to configure and deploy algorithms for collecting filtering messages by things
- Focuses on mobility aspects
- [http://www.openiot.eu/](http://www.openiot.eu/)

**IoT Toolkit**
- Aimed at developing a toolkit that glues several protocols available for the Cloud, for the things, and for the applications
Some CloudIoT Services

Xively | Open Sen.se | Thing Speak

- Collect data from things and store data on Cloud
- Typically provide an API
- Starting from them, companies created toolkits for integrations

- https://xively.com/
- http://open.sen.se/
- https://thingspeak.com/
A Research Project

ClouT

- Industrial, research partners, and city administrations (from EU and Japan)
- Aimed at developing infrastructures, services, tools, and applications to manage user-centric applications based on IoT and Cloud Integration

Declared targets of the project

- Enhanced public transportation
- Increased citizen participation
- Safety management
- City event monitoring
- Emergency management
Methodology of the Survey

Temporal Characterization of the Literature

Complementarity of Cloud and IoT

Application Scenarios

Main Platform, Services, and Research Projects

Hot Topics, Open Issues, and Future Directions
Hot Topics and Challenges

- CloudIoT complex scenario
- Specific capabilities to be satisfied
- Heterogeneous topics imposing specific challenges
- New concerns due to the lack of essential properties
  - E.g., trust in the service provider, knowledge about service level agreements etc.
Hot Topics and Challenges

- IoT services typically provided as *isolated vertical solutions*
- All system components tightly coupled to the specific application context
- Huge amounts of **heterogeneous things** to be properly addressed into the Cloud at different levels
- **Efficient, scalable, and easily-extensible** service delivery enabled by CloudIoT

- **Volume, variety, velocity**
- **Overall application performance** highly dependent on the properties of the data management service
Hot Topics and Challenges

- Defined as “the major enabler of IoT”
- Recent technological advances have made **efficient, low-cost, and low-power miniaturized devices** available for use in large-scale, remote sensing applications
- **Timely processing** of huge and streaming sensor data, subject to energy and network constraints and uncertainties
- Lack of mobility of common IoT devices
- New challenges introduced by smartphones as well as wearable electronics
Hot Topics and Challenges

- **Machine to machine (M2M) communication** among many heterogeneous devices with different protocols
- **Heterogeneity** can impact **performance**
- CloudIoT inherits the same (essential) **monitoring requirements** from Cloud
- Challenges related to monitoring are further affected by volume, variety, and velocity characteristics of IoT
Open Issues and Future Directions (1/2)

- Energy Efficient Sensing and Computing
  - Low-cost, low-power, and energy-constrained sensors
  - Compressive sensing and synchronous communication

- Fog Computing
  - Extension of computing to the edge of the network
  - Designed to support IoT applications
    - imposing latency constraints
    - requiring mobility and geo-distribution

- New Protocols
  - Need for Standards to facilitate the interconnection among heterogeneous smart objects
  - MAC and routing protocols are critical
  - Existing routing protocols (OSPF, IS-IS, AODV, OLSR) do not satisfy requirements of Low Power and Lossy Networks
Participative Sensing
- Relying on users volunteering data is a severe limitation
- Missing samples is critical in people-centric sensing
- Proper incentives must be identified

Complex Data Mining
- High number of big producers, high frequency of generation
- The gap between available and processed data is getting wider
- Percentage that an organization can analyze is on decline
Thanks!

Questions?

valerio.persico@unina.it