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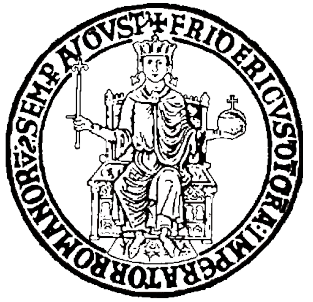


On the Integration of Cloud Computing and Internet of Things

FiCloud-2014, August 27 2014 – Barcelona, Spain

Alessio Botta, Walter de Donato, Valerio Persico, Antonio Pescapè

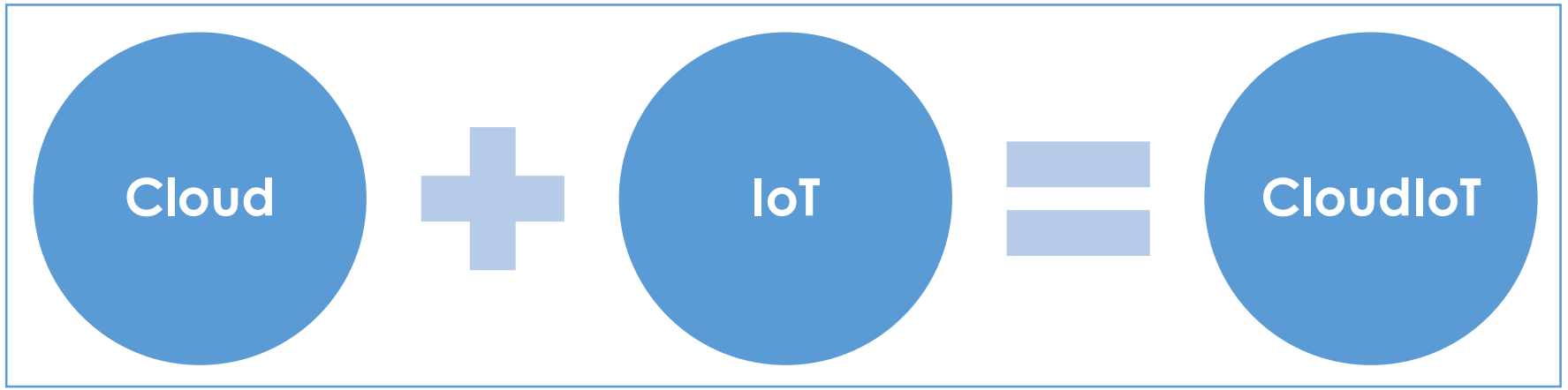
The *CloudIoT* Paradigm

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

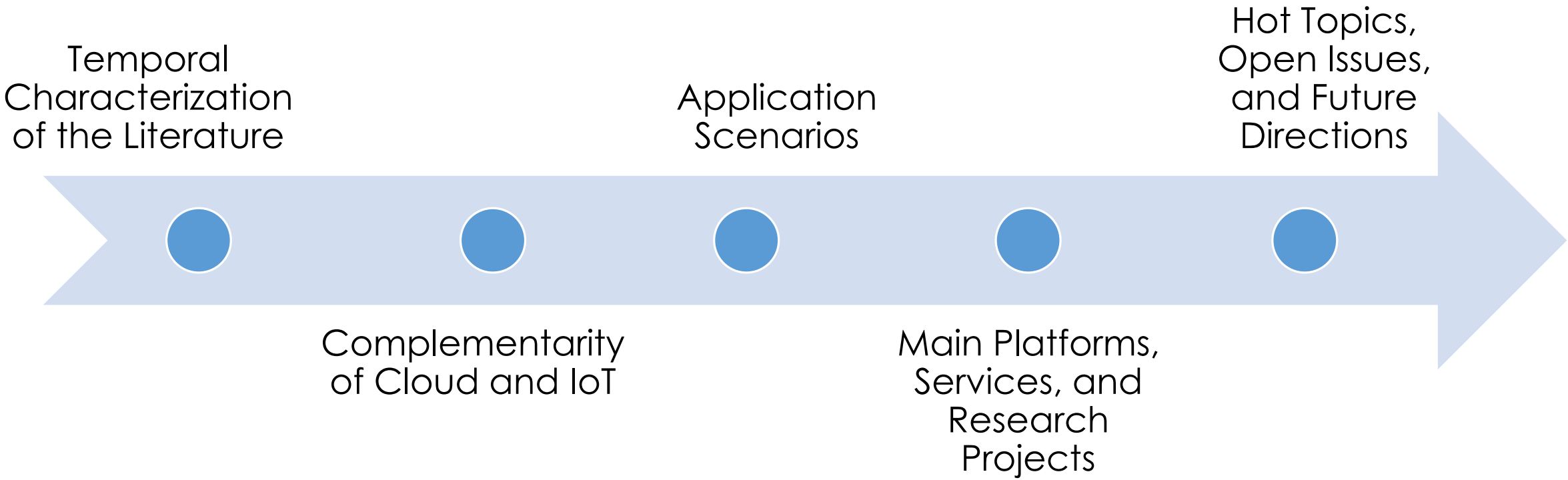


The *CloudIoT* Paradigm: a Survey

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



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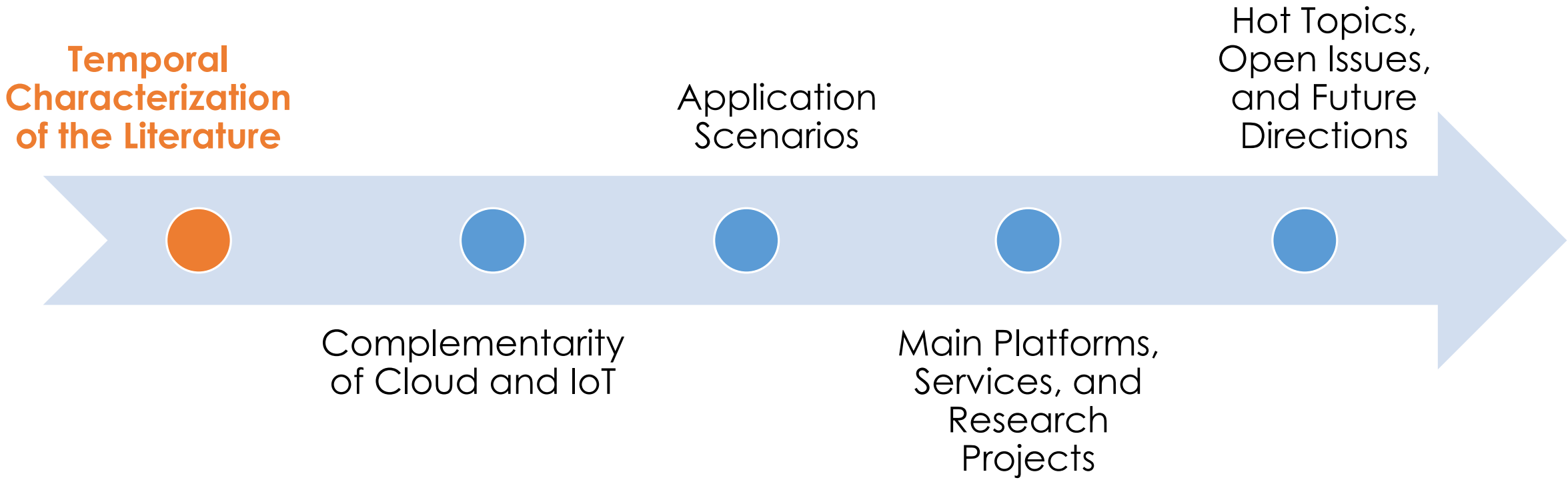
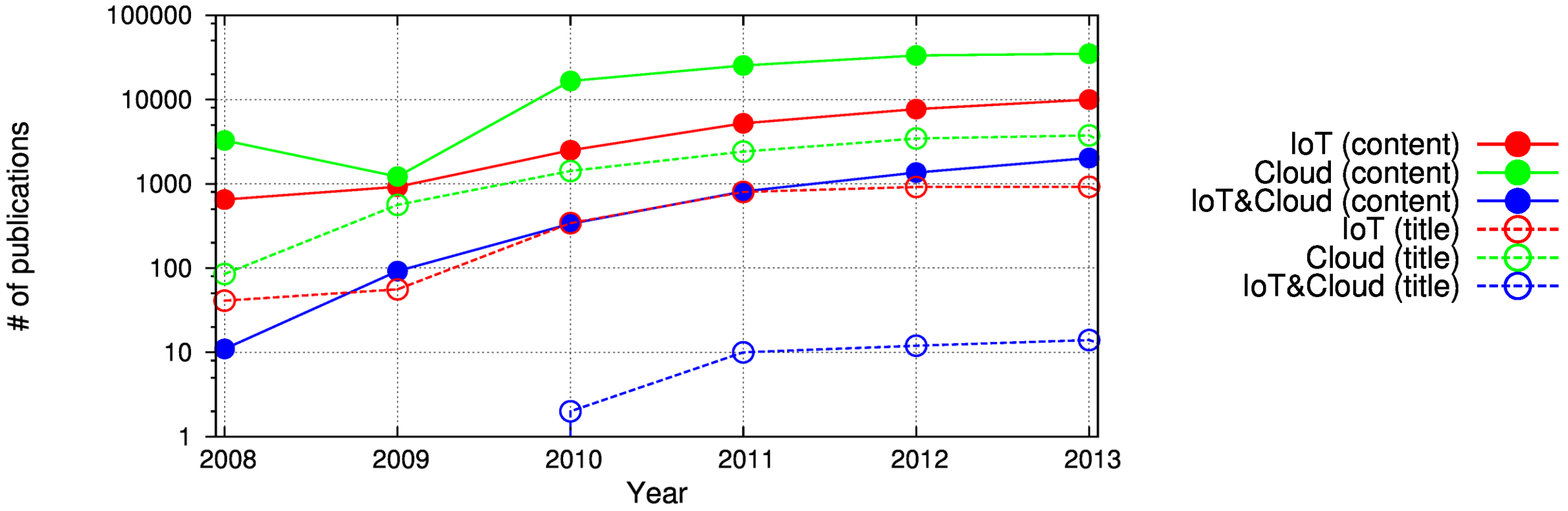


Temporal Characterization of the Literature



- Research and Interest Trends about Cloud and IoT
- Source: Google Scholar

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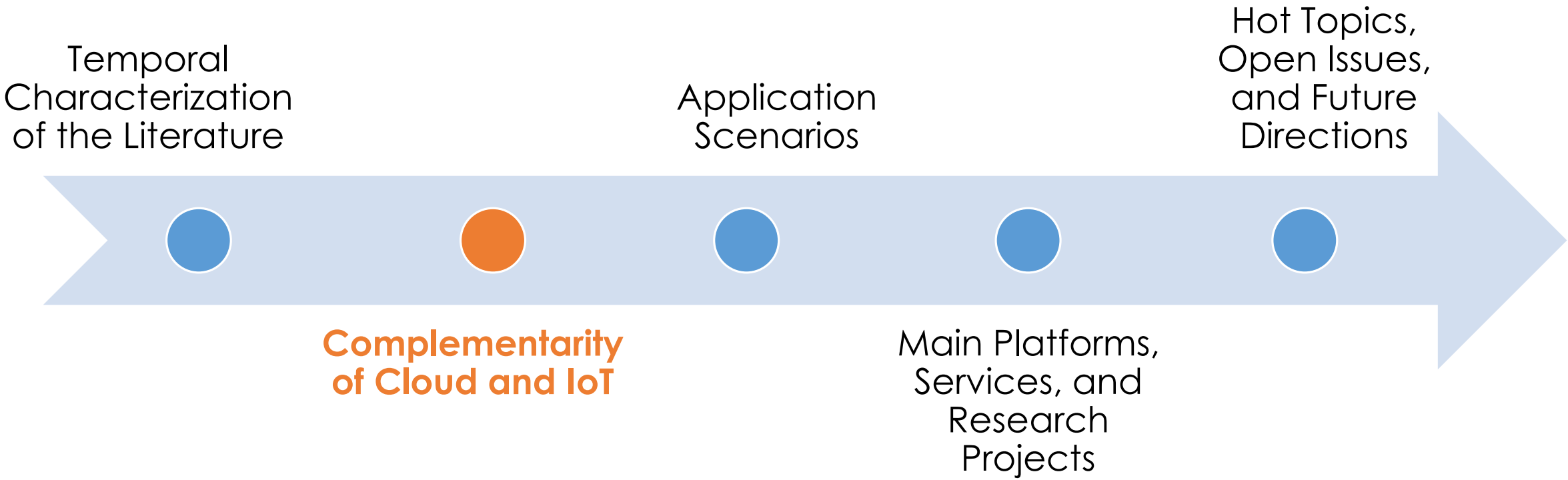
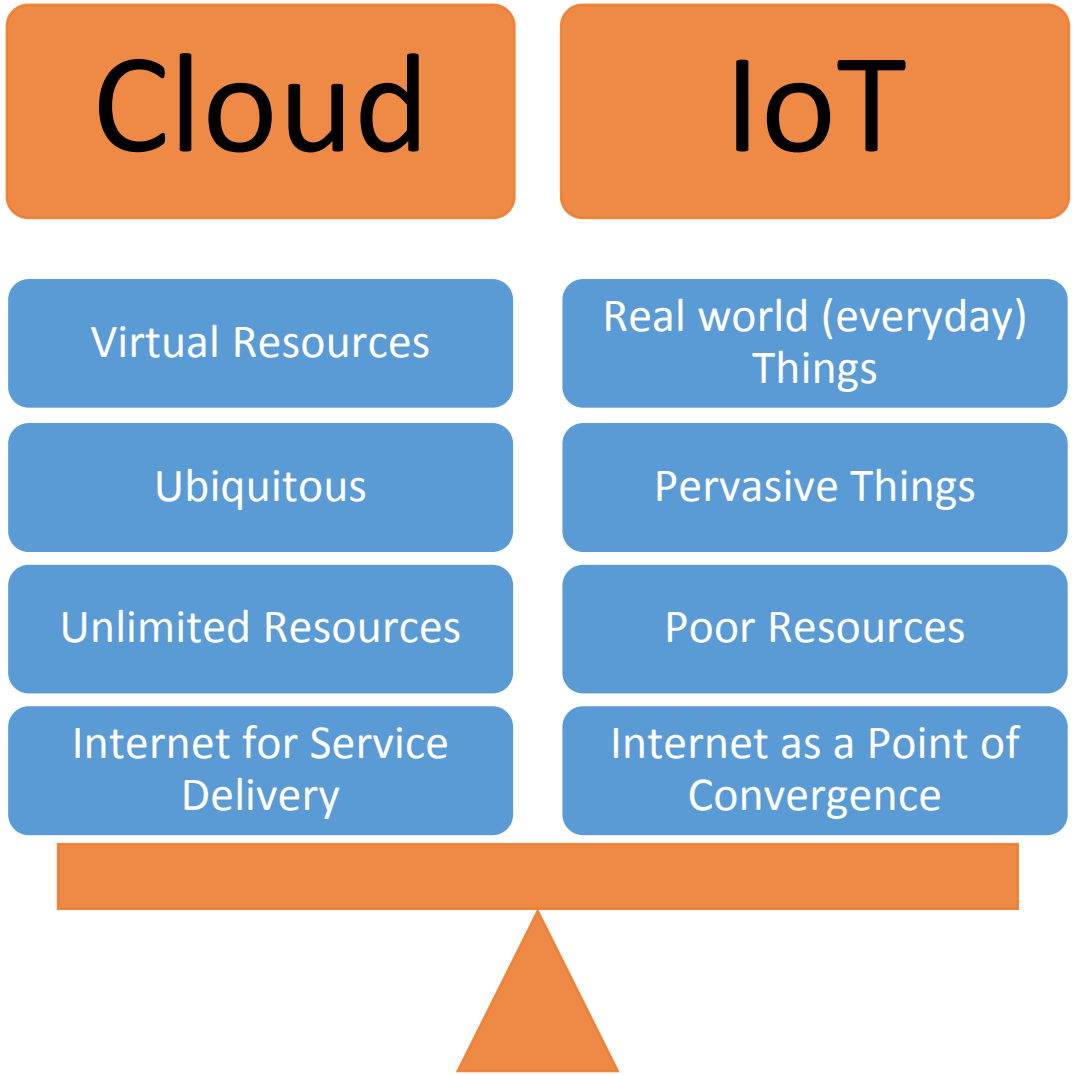


Complementarity of Cloud and IoT



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

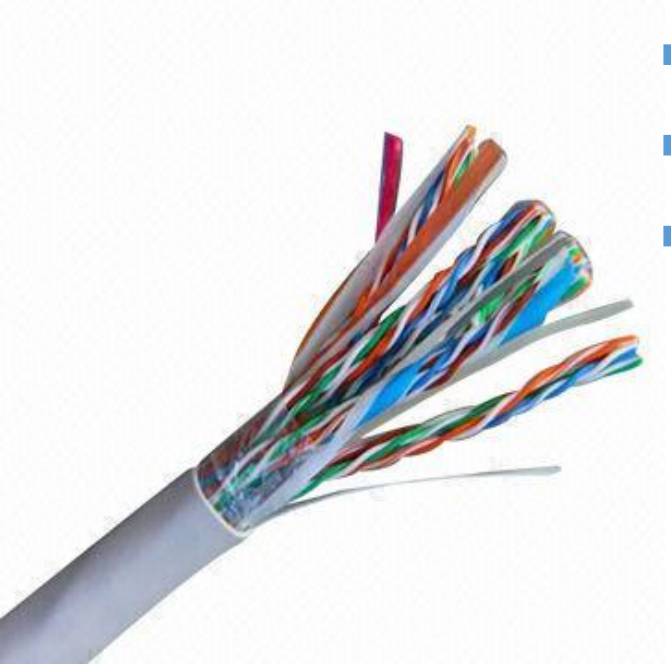
The Need for Integration: Computation

- 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

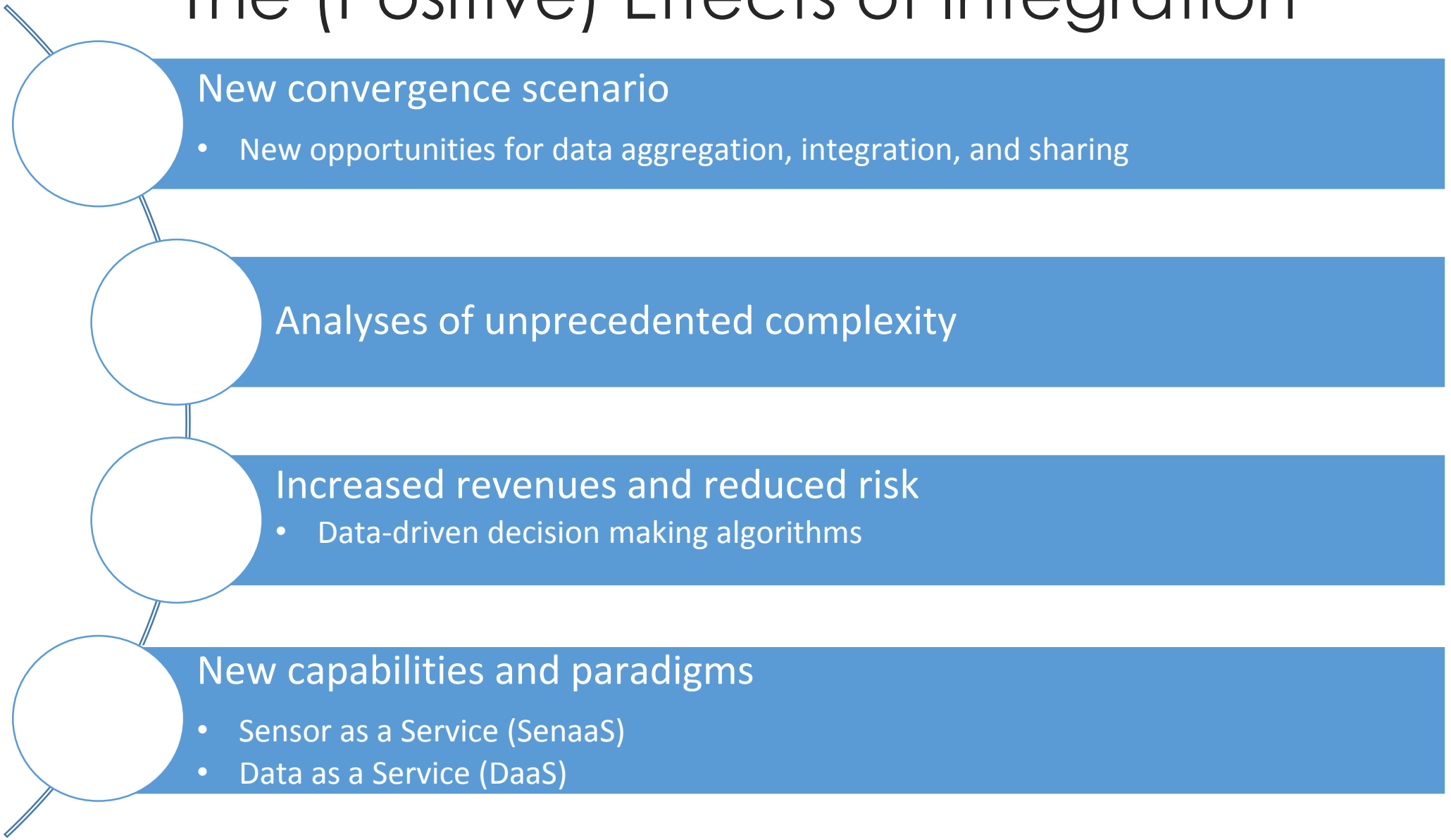
The Need for Integration: Communication

- 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



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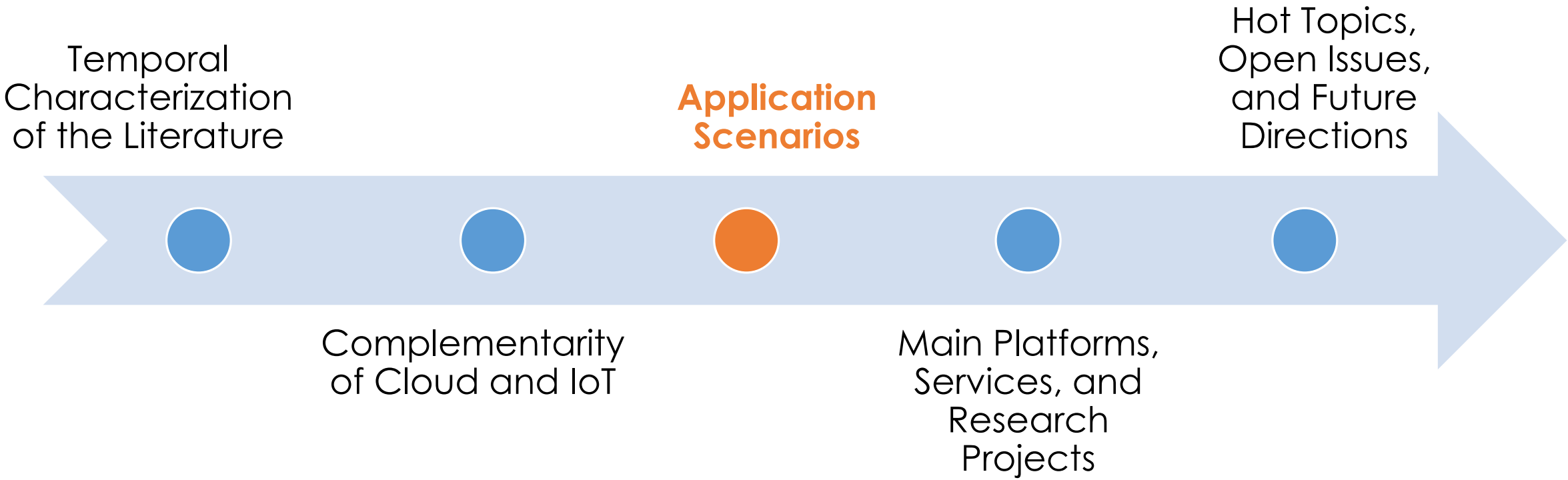
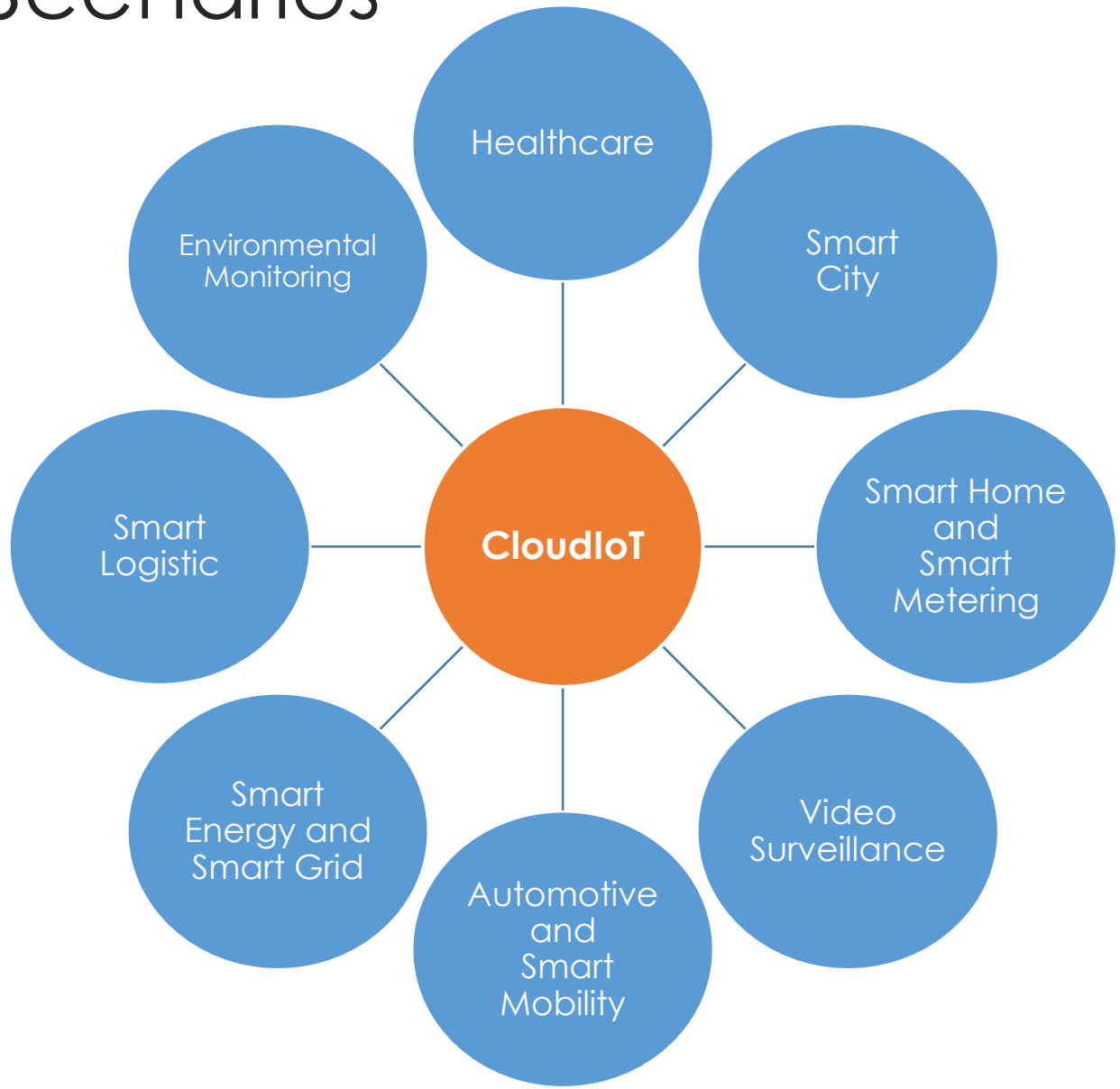


Application Scenarios

- A wide set of applications is ***made possible*** or ***significantly improved*** by CloudIoT



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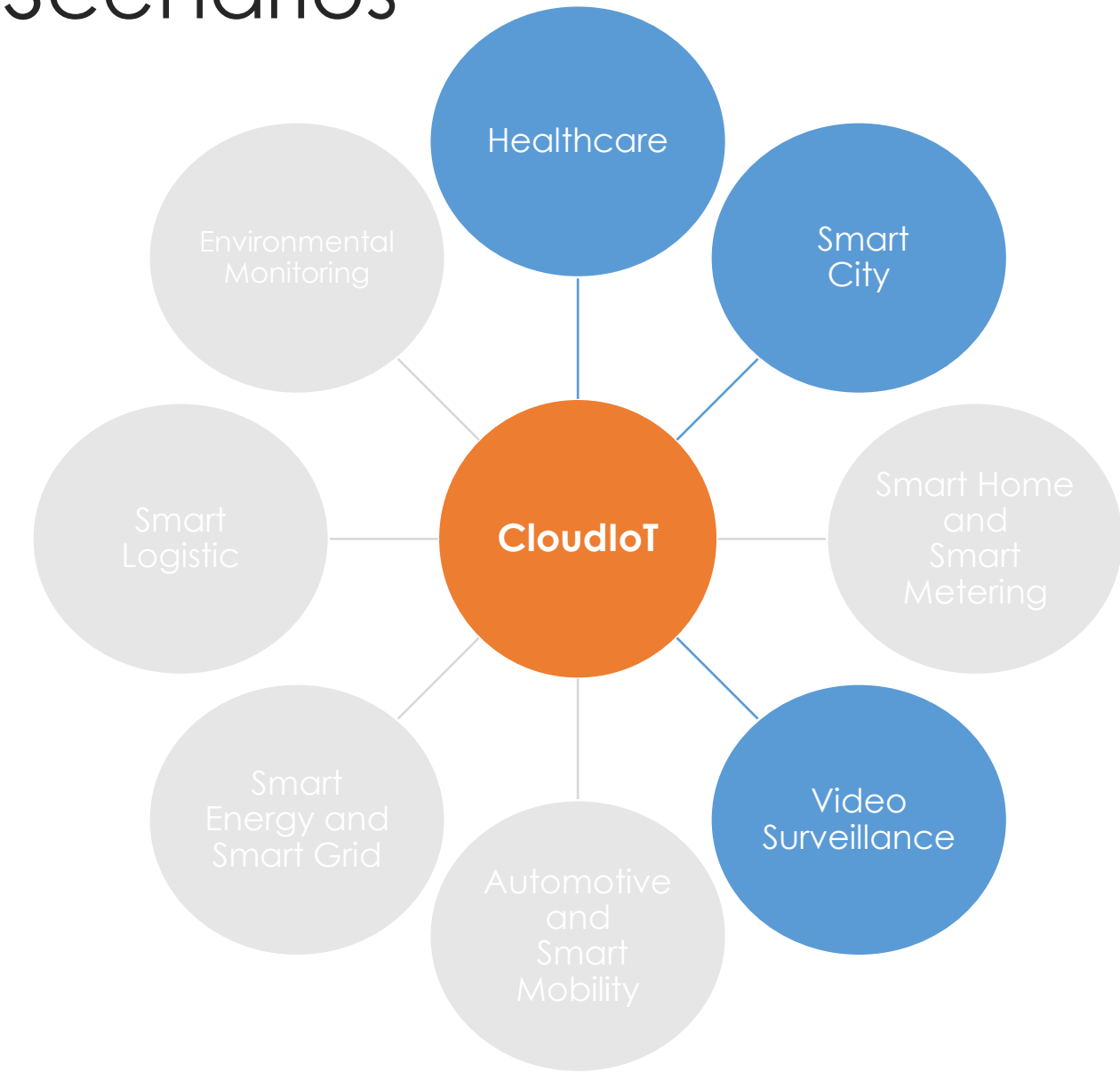


CloudIoT and Healthcare

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

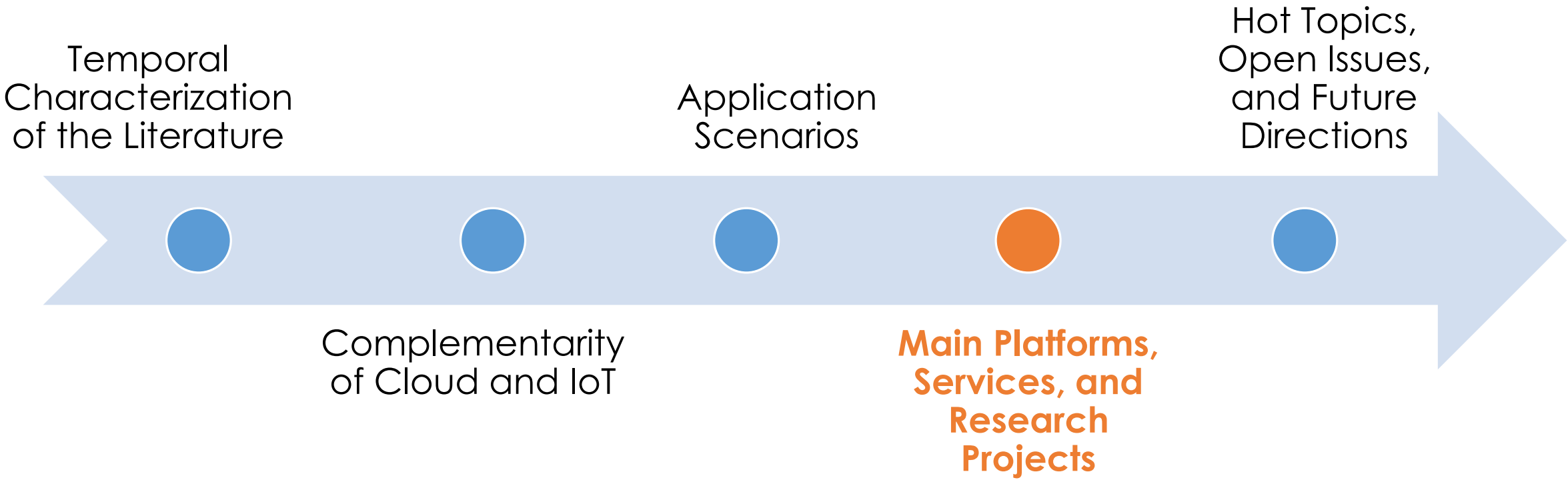
- Requirements of processing
  - Video processing
  - Computer vision algorithms
  - Pattern recognition modules

- 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



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/

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/

IoT Toolkit

- Aimed at developing a toolkit that glues several protocols available for the Cloud, for the things, and for the applications
- http://iot-toolkit.com/

(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

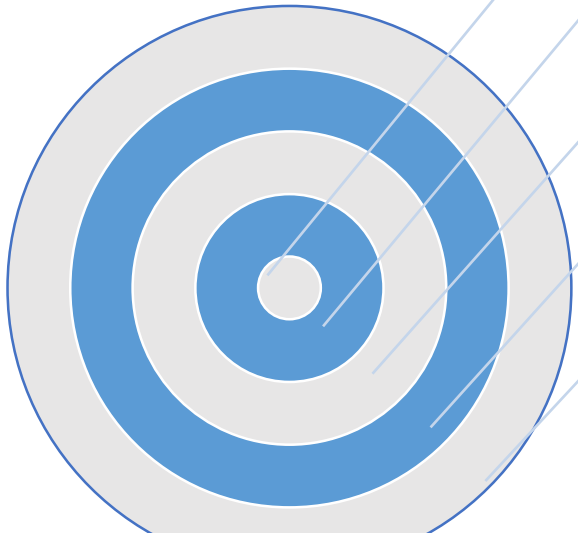
- https://xively.com/
- http://open.sen.se/
- https://thingspeak.com/

A Research Project

ClouT

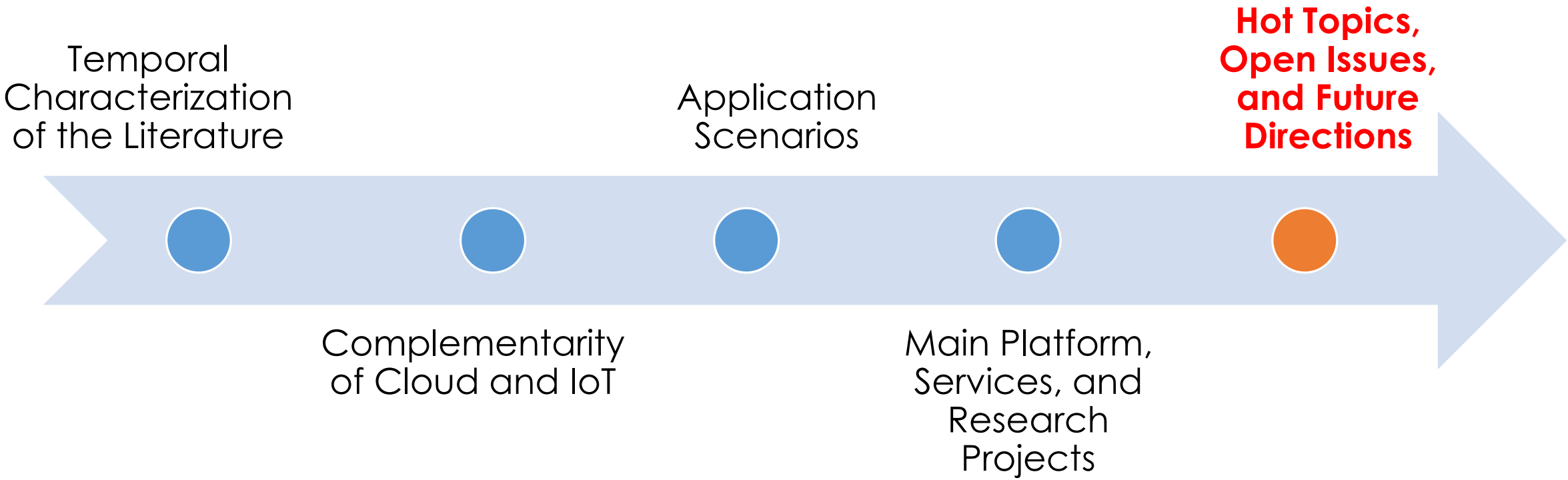
- Industrial, research partners, and city administrations (from EU and Japan)
- Aimed at developing infrastructures, services, tools, and applications to manage user-centric applications based on IoT and Cloud Integration

Declared targets of the project

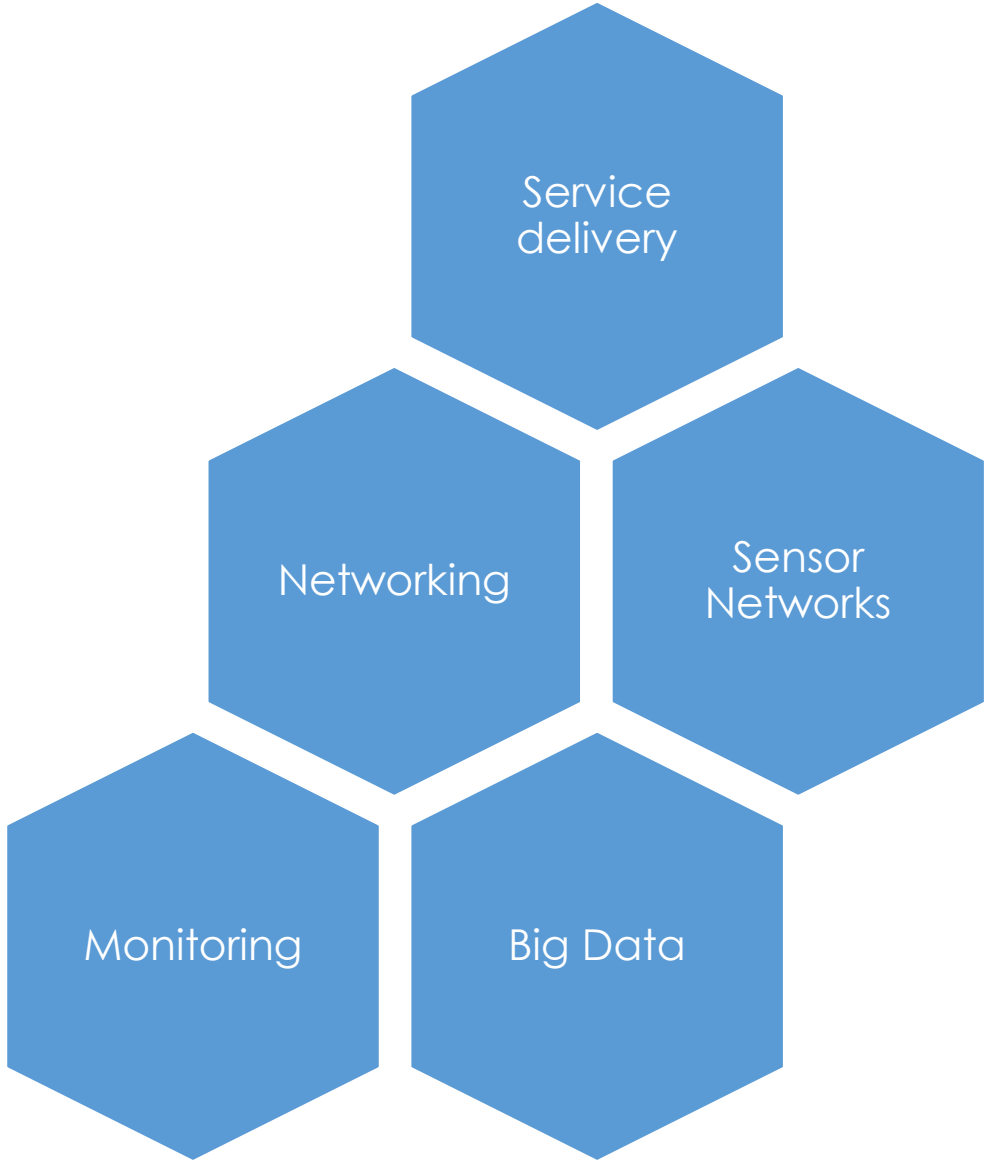


- Enhanced public transportation
- Increased citizen participation
- Safety management
- City event monitoring
- Emergency management

Methodology of the Survey

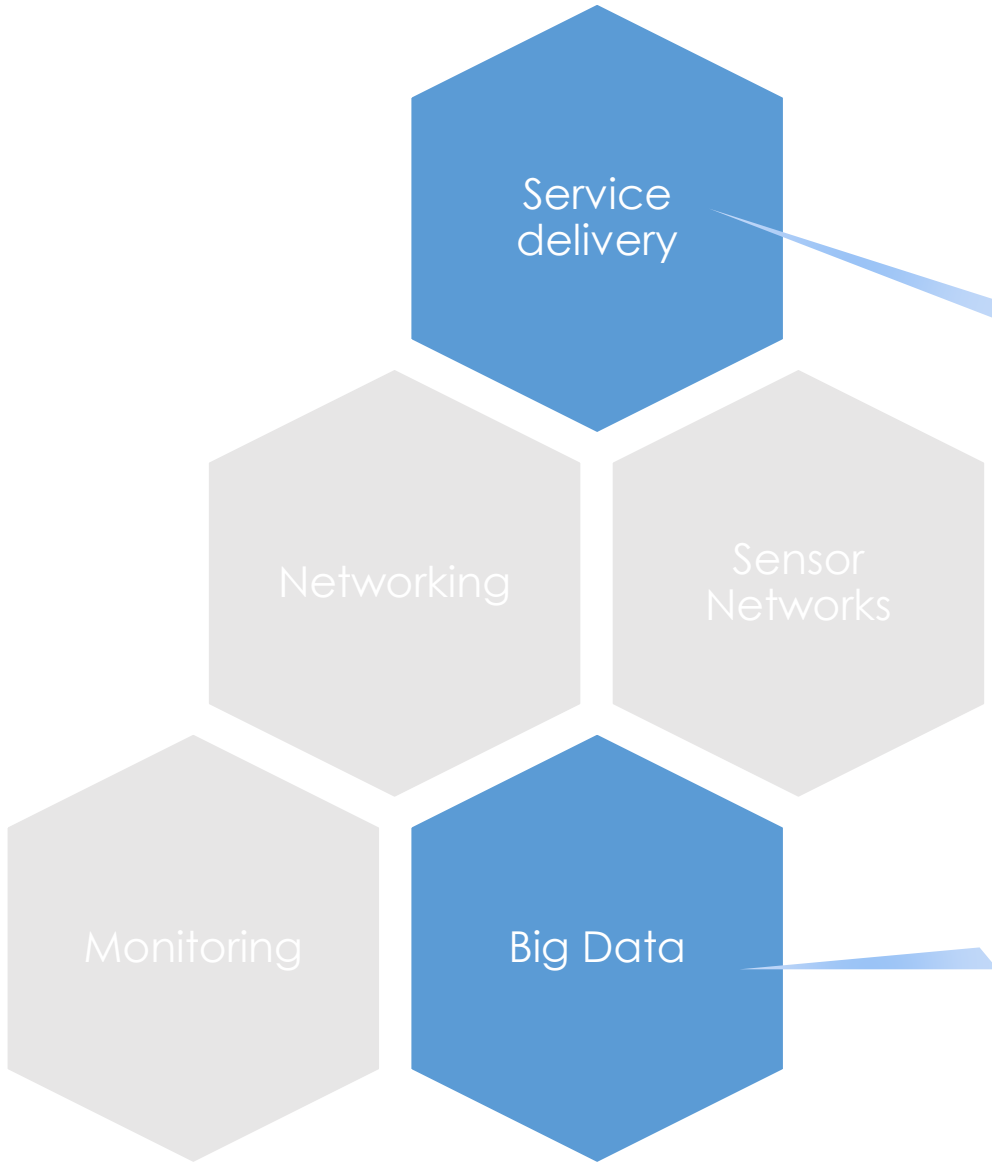


Hot Topics and Challenges



- 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.

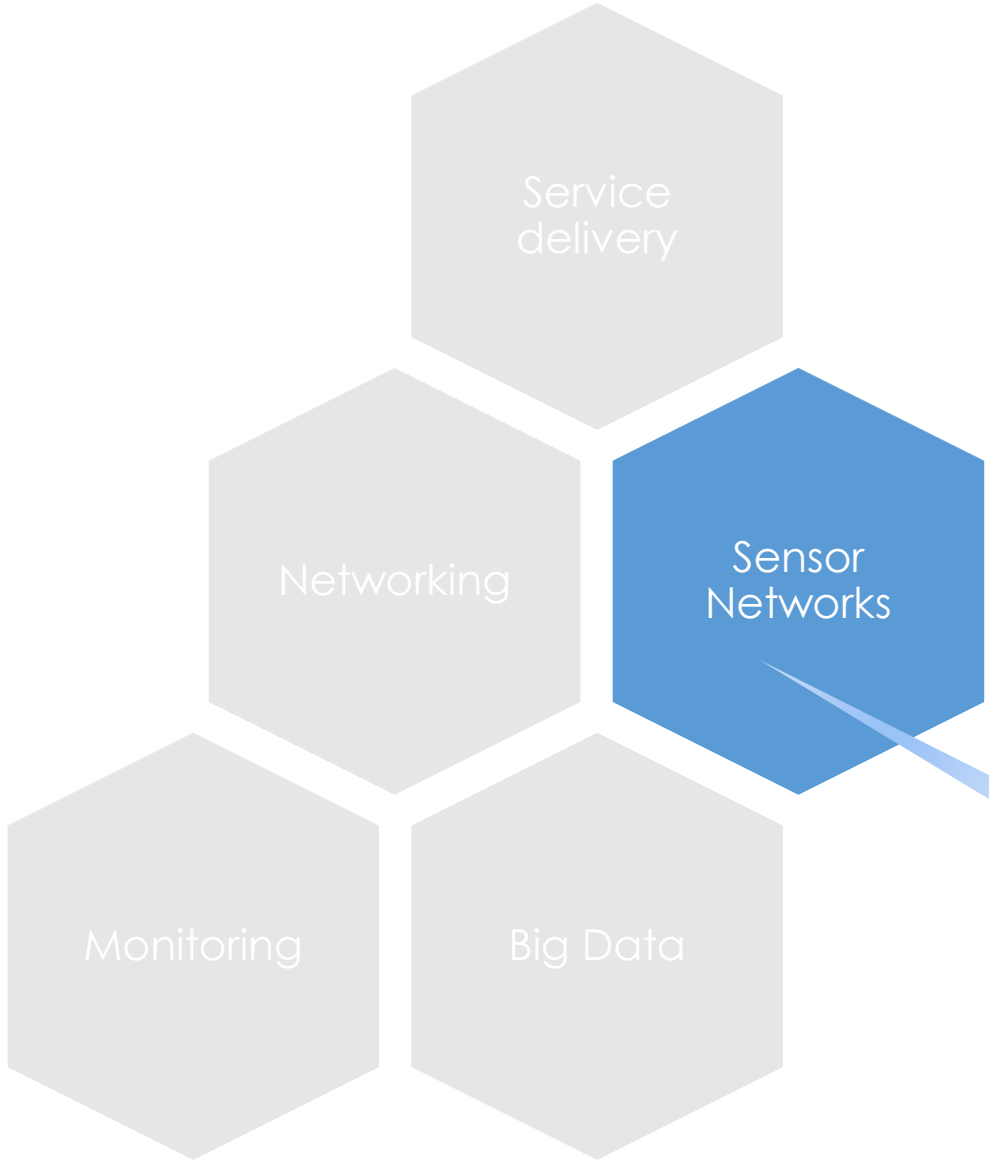
Hot Topics and Challenges



- 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

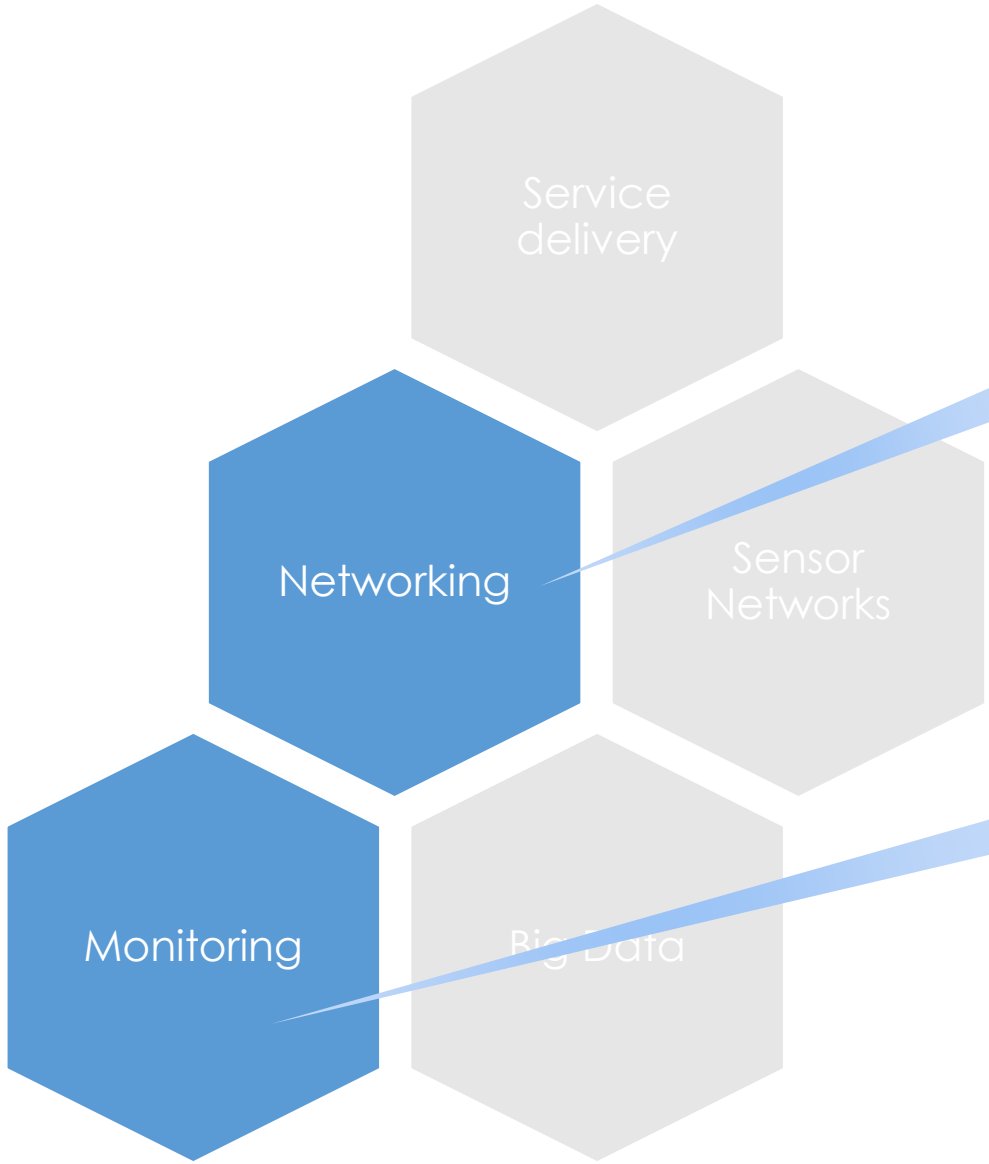
- Volume, variety, velocity
- **Overall application performance** highly dependent on the properties of the data management service

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

Open Issues and Future Directions (2/2)

- 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?

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