Green Cloud

Green Cloud?

- Green computing is the environmentally responsible and eco-friendly use of computers and their resources.
- In broader terms, it is also defined as the study of designing, manufacturing or engineering, using and disposing of computing devices in a way that reduces their environmental impact.
- Green Cloud computing is envisioned to achieve not only efficient processing and utilization of computing infrastructure, but also minimize energy consumption.

Cloud – Challenge

- Gartner Report 2007: IT industry contributes 2% of world's total CO_2 emissions
- U.S. EPA Report 2007: 1.5% of total U.S. power consumption used by data centers which has more than doubled since 2000 and costs $4.5 billion

>> Need of Green Cloud Computing....

Importance of Energy

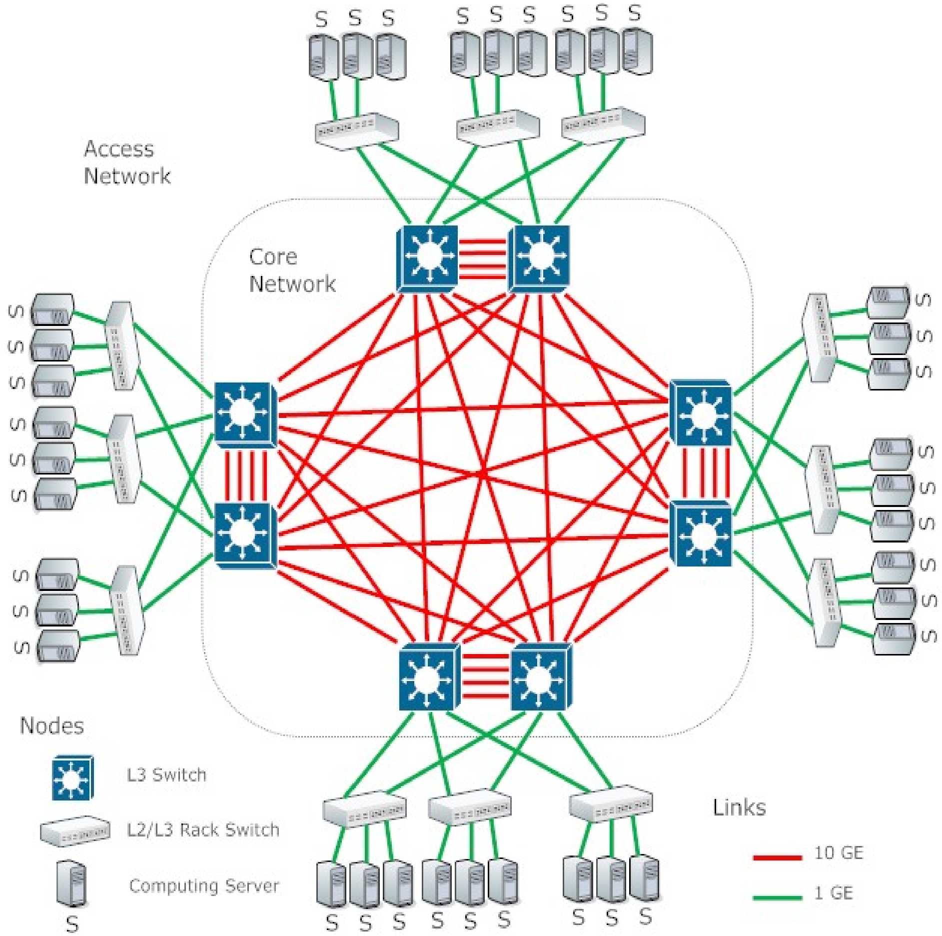
- Increased computing demand
  - Data centers are rapidly growing
  - Consume 10 to 100 times more energy per square foot than a typical office building
- Energy cost dynamics
  - Energy accounts for 10% of data center operational expenses (OPEX) and can rise to 50% in the next few years
  - Accompanying cooling system costs $2-$5 million per year

Typical Data Center Energy Consumption

- Cooling system 45%
- IT Equipment 40%
- Power distribution 15%

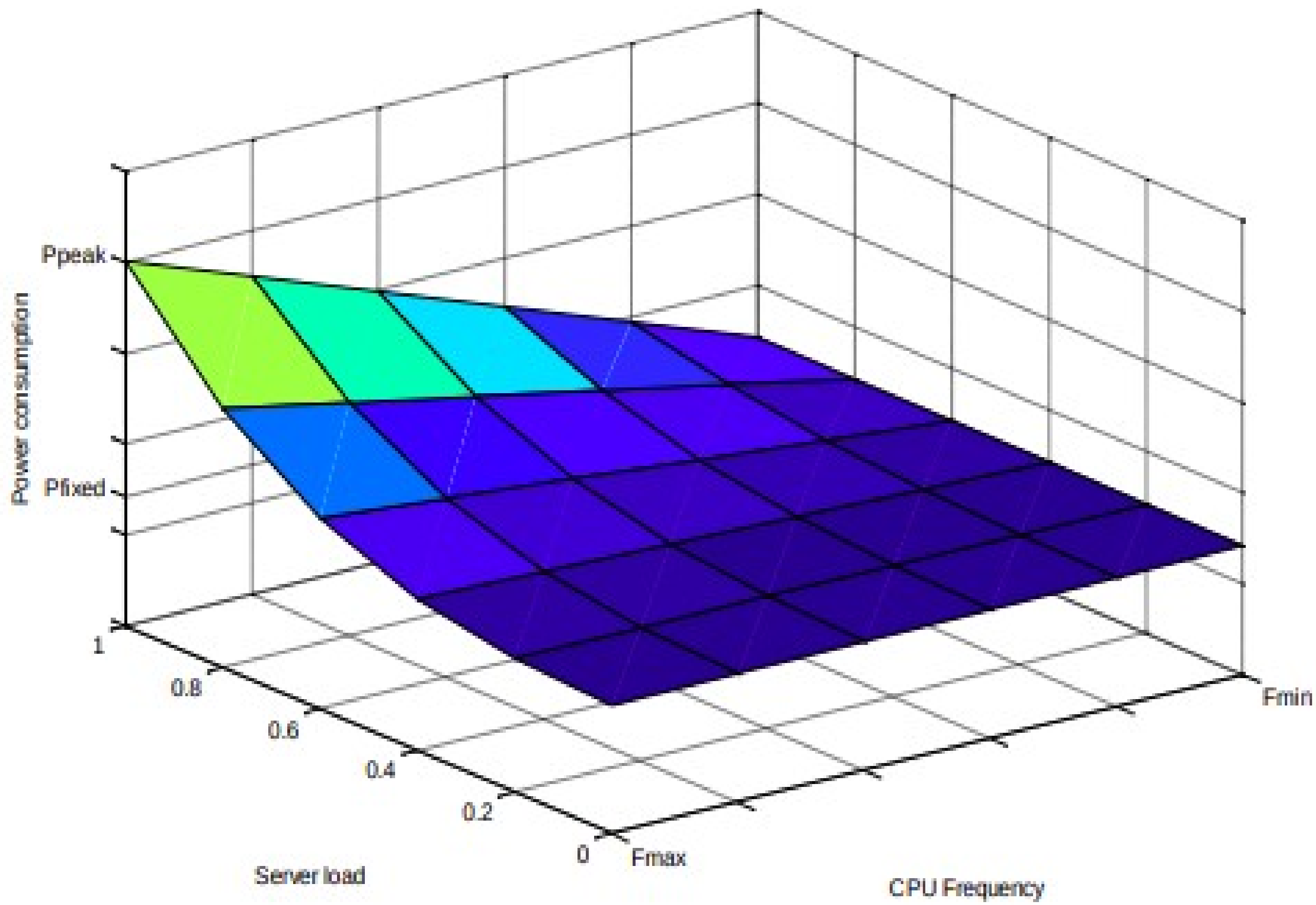
DC Architecture - Past

- Two-tier DC architecture
  - Access and Core layers
  - 1 GE and 10 GE links
  - Full mesh core network
  - Load balancing using ICMP



DC Server Energy Model

$$P = P_{fixed} + P_f * f^3$$



DC Network Switches' Energy Model

$$P_{switch} = P_{chasis} + n_{linecards} \cdot P_{linecard} + \sum_{i=0}^{R} n_{portsr} \cdot P_r$$

Impact of Cloud DC on Environment

- Data centers are not only expensive to maintain, but also unfriendly to the environment.
- Carbon emission due to Data Centers worldwide is now more than both Argentina and the Netherlands emission.
- High energy costs and huge carbon footprints are incurred due to the massive amount of electricity needed to power and cool the numerous servers hosted in these data centers.

Performance <-> Energy Efficiency

- As energy costs are increasing while availability decreases, there is a need to shift focus from optimizing data center resource management for pure performance alone to optimizing for energy efficiency while maintaining high service level performance.

CSP Initiatives

- Cloud service providers need to adopt measures to ensure that their profit margin is not dramatically reduced due to high energy costs.
- Amazon.com’s estimate the energy-related costs of its data centers amount to 42% of the total budget that include both direct power consumption and the cooling infrastructure amortized over a 15-year period.
- Google, Microsoft, and Yahoo are building large data centers in barren desert land surrounding the Columbia River, USA to exploit cheap hydroelectric power.

Power Usage Effectiveness (PUE)

- $PUE = \frac{Overall\ Power}{Power\ Delivered}$
- $1 \leq PUE \leq \infty$
- “IT Load”
- IT Manager & Infrastructure Manager
- CUE
- Measurement, Modeling, Quantify
- Average PUE in US = 1.91

Conclusions

- Clouds are essentially Data Centers hosting application services offered on a subscription basis. However, they consume high energy to maintain their operations.
  - high operational cost + environmental impact
- Presented a Carbon Aware Green Cloud Framework to improve the carbon footprint of Cloud computing.
- Open Issues: Lots of research to be carried out for Maximizing Efficiency of Green Data Centers and Developing Regions to benefit the most.

Sensor Cloud Computing

Motivation

- Increasing adoption of sensing technologies (e.g., RFID, cameras, mobile phones)
- Internet has become a source of real time information (e.g., through blogs, social networks, live forums) for events happening around us
- Cloud computing has emerged as an attractive solution for dealing with the “Big Data” revolution
- By combining data obtained from sensors with that from the internet, we can potentially create a demand for resources that can be appropriately met by the cloud

Wireless Sensor Network (WSNs)

- Seamlessly couples the physical environment with the digital world
- Sensor nodes are small, low power, low cost, and provide multiple functionalities
  - Sensing capability, processing power, memory, communication bandwidth, battery power.
- In aggregate, sensor nodes have substantial data acquisition and processing capability
- Useful in many application domains – Environment, Healthcare, Education, Defense, Manufacturing, Smart Home, etc.

Limitations of Sensor Networks

- Very challenging to scale sensor networks to large sizes
- Proprietary vendor-specific designs. Difficult for different sensor networks to be interconnected
- Sensor data cannot be easily shared by different groups of users.
- Insufficient computational and storage resources to handle large-scale applications.
- Used for fixed and specific applications that cannot be easily changed once deployed.
- Slow adoption of large-scale sensor network applications.

Limitations of Cloud Computing!

- The immense power of the Cloud can only be fully exploited if it is seamlessly integrated into our physical lives.
- That means – providing the real world's information to the Cloud in real time and getting the Cloud to act and serve us instantly.
- That is – adding the sensing capability to the Cloud

Need to integrate Sensors with Cloud!

- Acquisition of data feeds from numerous body area (blood sugar, heat, perspiration, etc) and wide area (water quality, weather monitoring, etc.) sensor networks in real time.
- Real-time processing of heterogeneous data sources in order to make critical decisions.
- Automatic formation of workflows and invocation of services on the cloud one after another to carry out complex tasks.
- Highly swift data processing using the immense processing power of the cloud to provide quick response to the user.

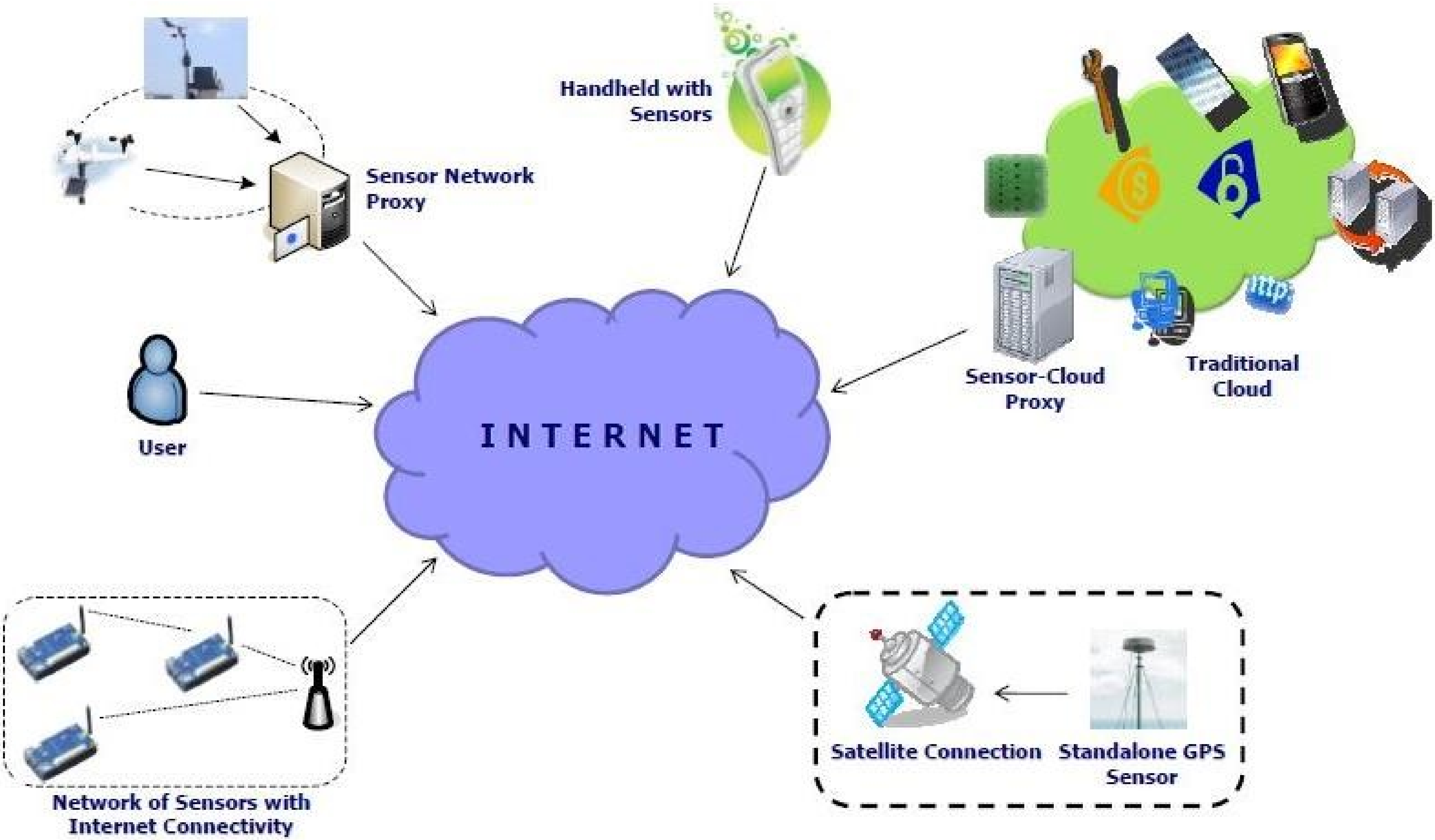
What is Sensor Cloud Computing?

- An infrastructure that allows truly pervasive computation using sensors as interface between physical and cyber worlds, the data-compute clusters as the cyber backbone and the internet as the communication medium
- It integrates large-scale sensor networks with sensing applications and cloud computing infrastructures.
- It collects and processes data from various sensor networks.
- Enables large-scale data sharing and collaborations among users and applications on the cloud.
- Delivers cloud services via sensor-rich devices.
- Allows cross-disciplinary applications that span organizational boundaries.

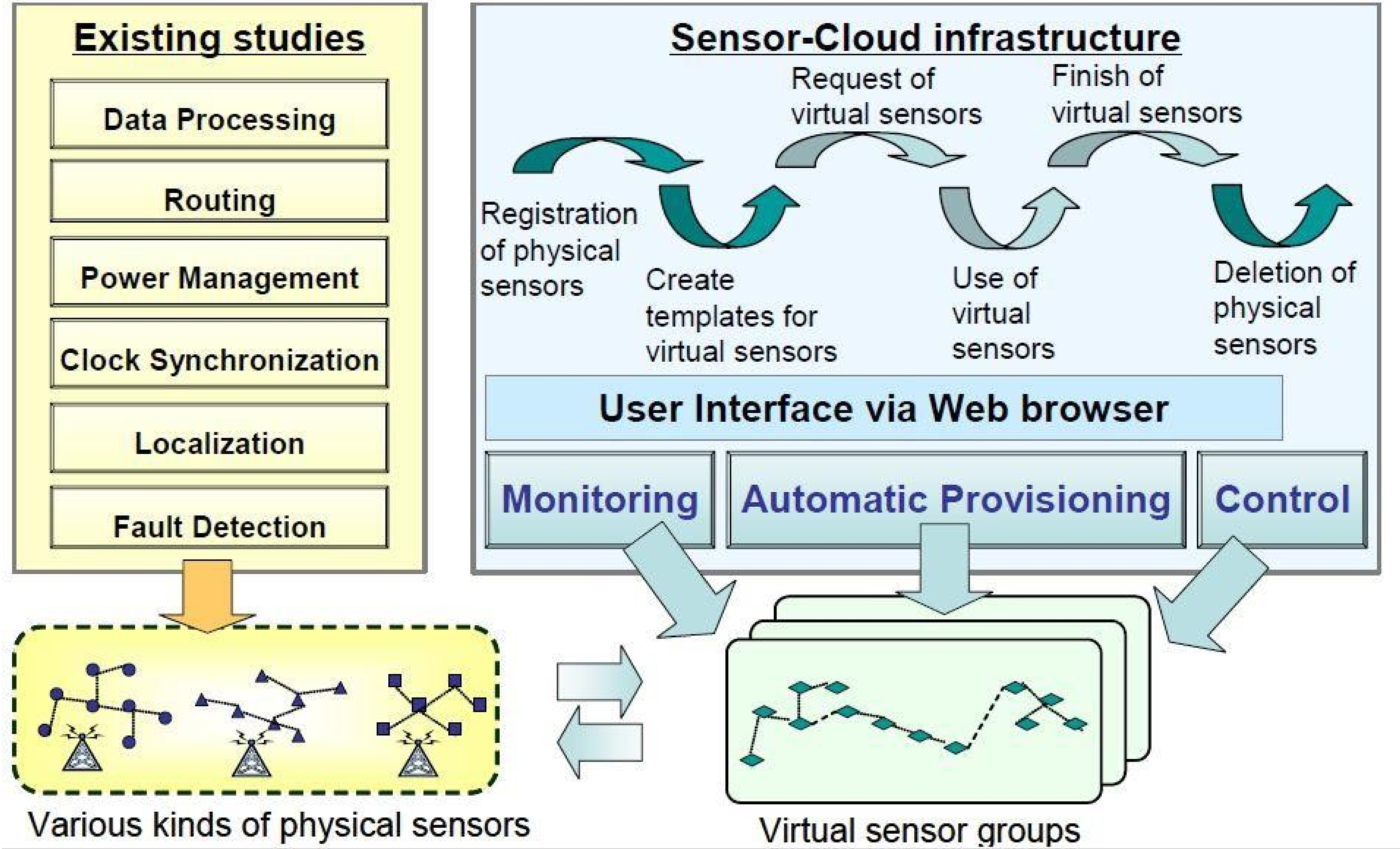
Sensor Cloud?

- Enables users to easily collect, access, process, visualize, archive, share and search large amounts of sensor data from different applications.
- Supports complete sensor data life cycle from data collection to the backend decision support system
- Allows sharing of sensor resources by different users and applications under flexible usage scenarios.
- Enables sensor devices to handle specialized processing tasks.

Overview of Sensor-Cloud Framework



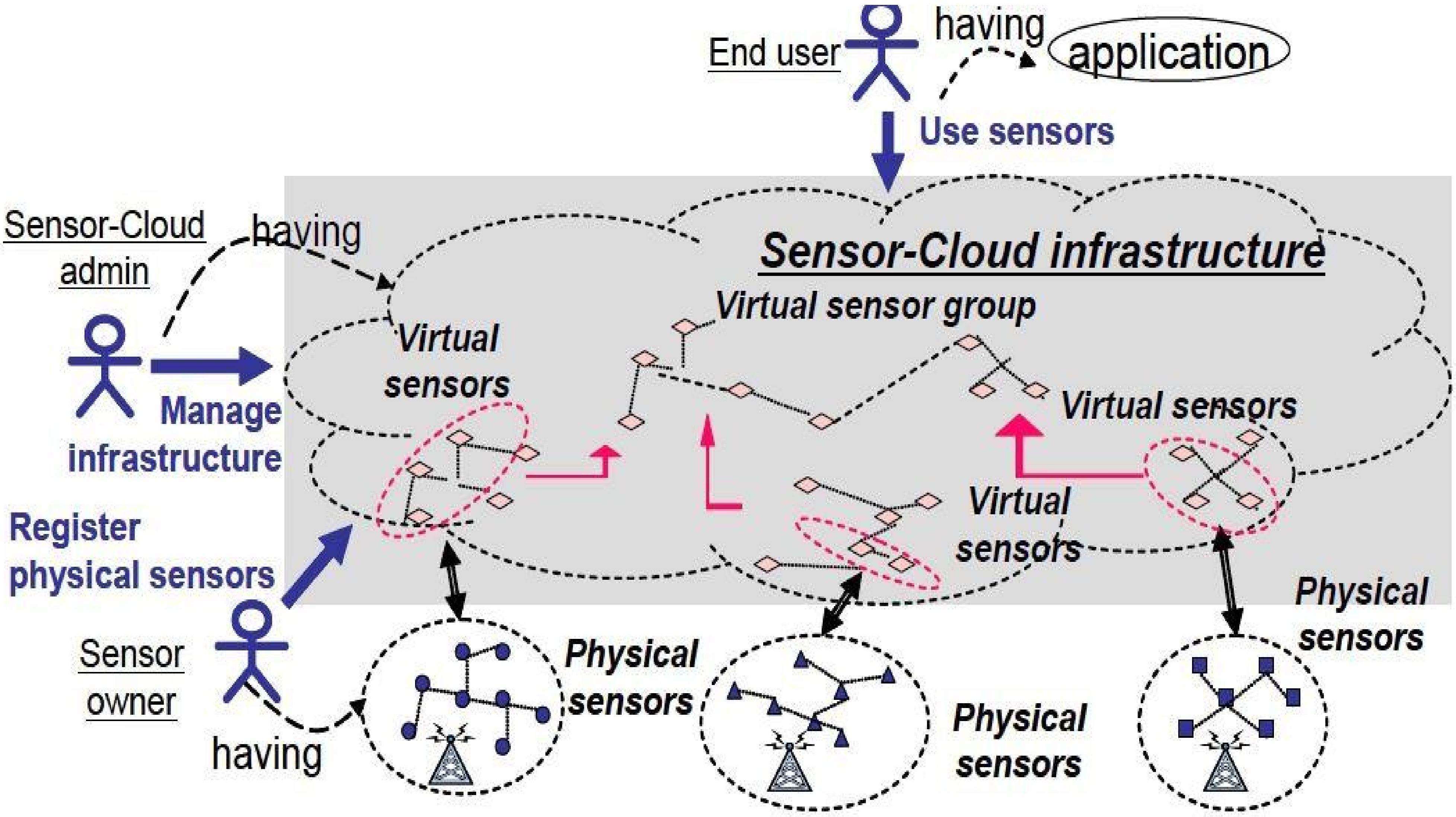
Overview of Sensor Cloud Infrastructure



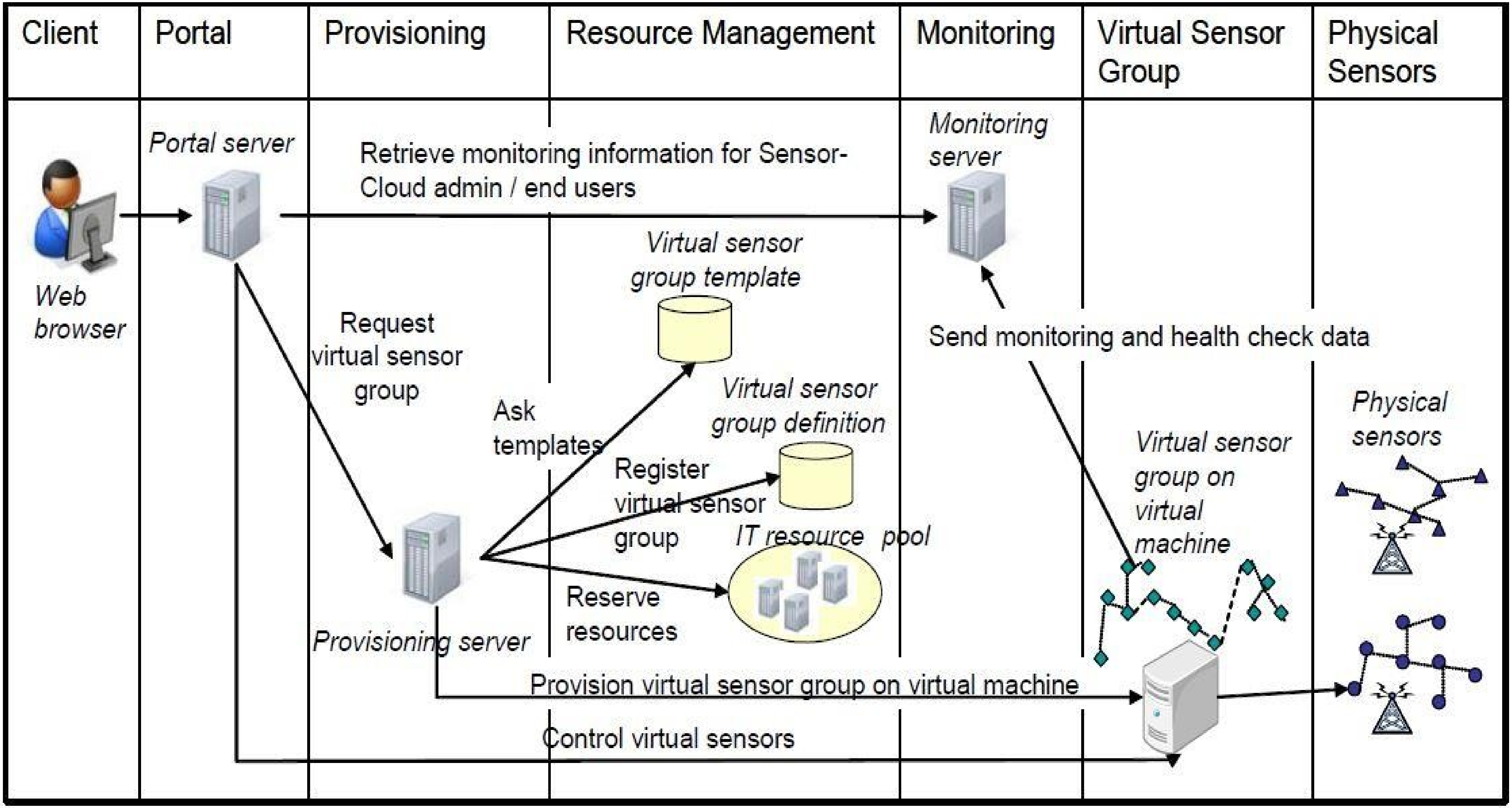
Virtual Sensors?

- A virtual sensor is an emulation of a physical sensor that obtains its data from underlying physical sensors.
- Virtual sensors provide a customized view to users using distribution and location transparency.
- In wireless sensors, the hardware is barely able to run multiple tasks at a time and difficult to run on multiple VMs, such as in traditional cloud computing.
- To overcome this problem, virtual sensors act as an image in the software of the corresponding physical sensors.
- The virtual sensors contain metadata about the physical sensors and the user currently holding that virtual sensor.

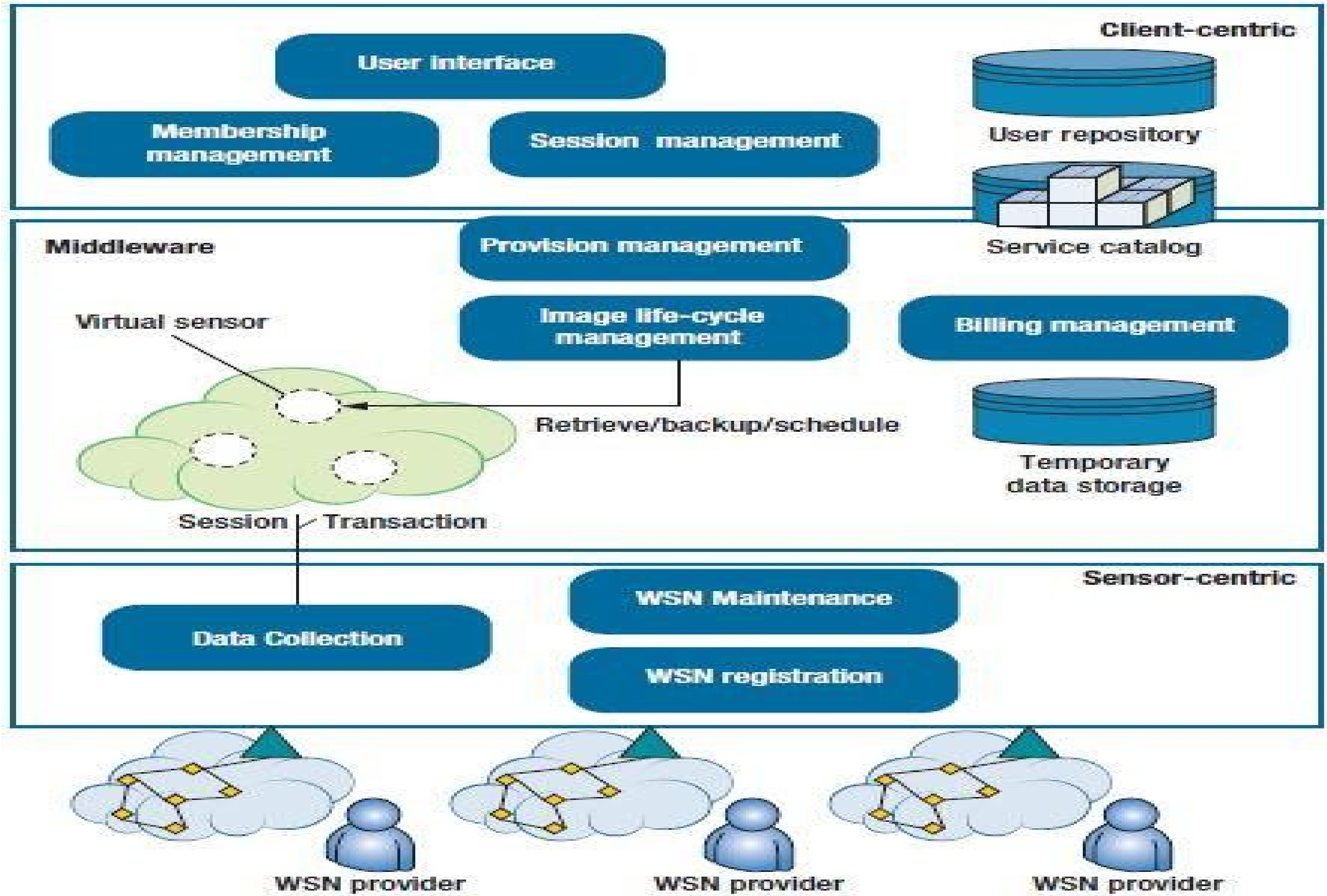
Relationship among Actors and Sensor Cloud Infrastructure



System Architecture of Sensor Cloud Infrastructure



A Layered Sensor Cloud Architecture



Summary

- Sensor-Cloud infrastructure virtualizes sensors and provides the management mechanism for virtualized sensors
- Sensor-Cloud infrastructure enables end users to create virtual sensor groups dynamically by selecting the templates of virtual sensors or virtual sensor groups with IT resources.
- Sensor-Cloud infrastructure focuses on Sensor system management and Sensor data management
- Sensor clouds aim to take the burden of deploying and managing the network away from the user by acting as a mediator between the user and the sensor networks and providing sensing as a service .

IoT Cloud

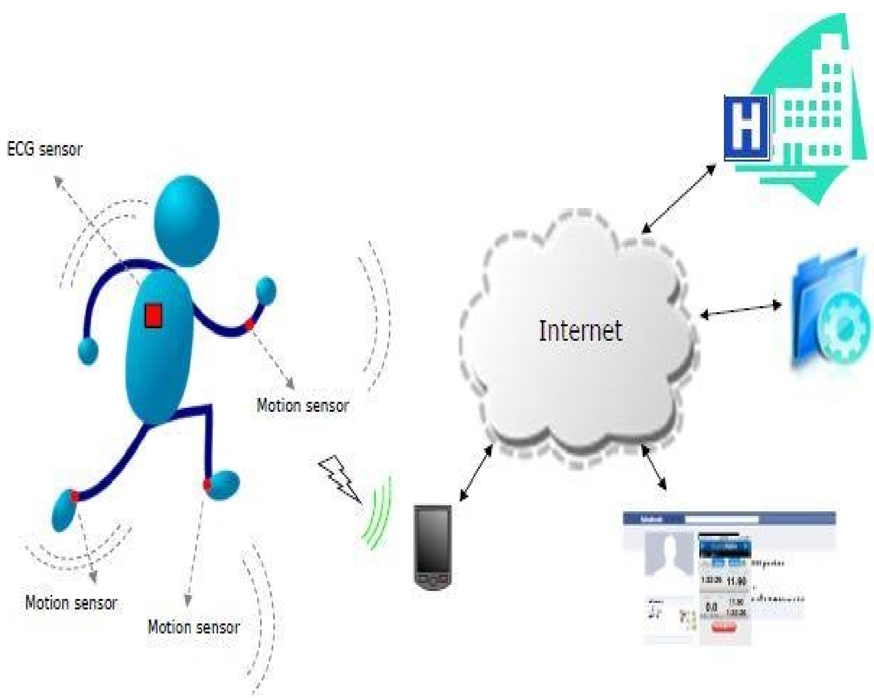
Motivation

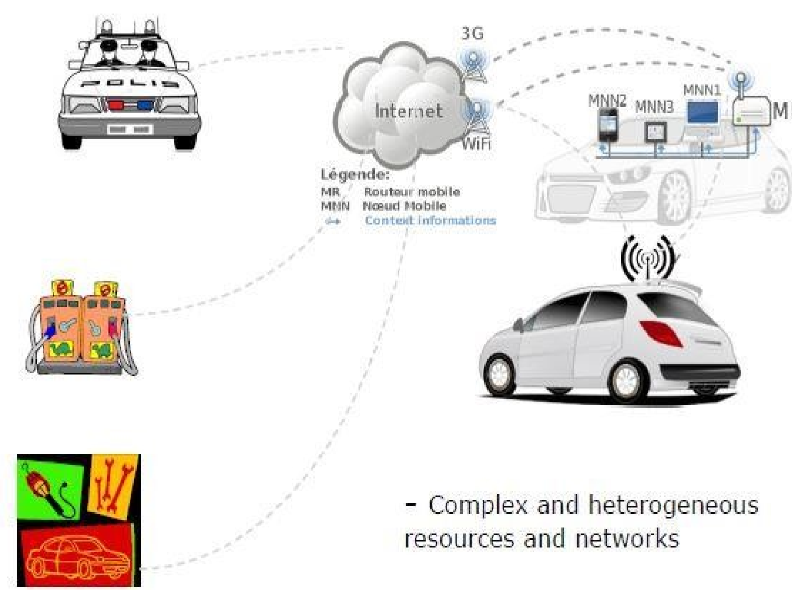
- Increasing adoption of sensing technologies (e.g., RFID, cameras, mobile phones)
- Sensor devices are becoming widely available
- Wireless sensor technology play a pivotal role in bridging the gap between the physical and virtual worlds, and enabling things to respond to changes in their physical environment.
- Sensors collect data from their environment, generating information and raising awareness about context.
- **Example:** Sensors in an electronic jacket can collect information about changes in external temperature and the parameters of the jacket can be adjusted accordingly

Internet of Things!

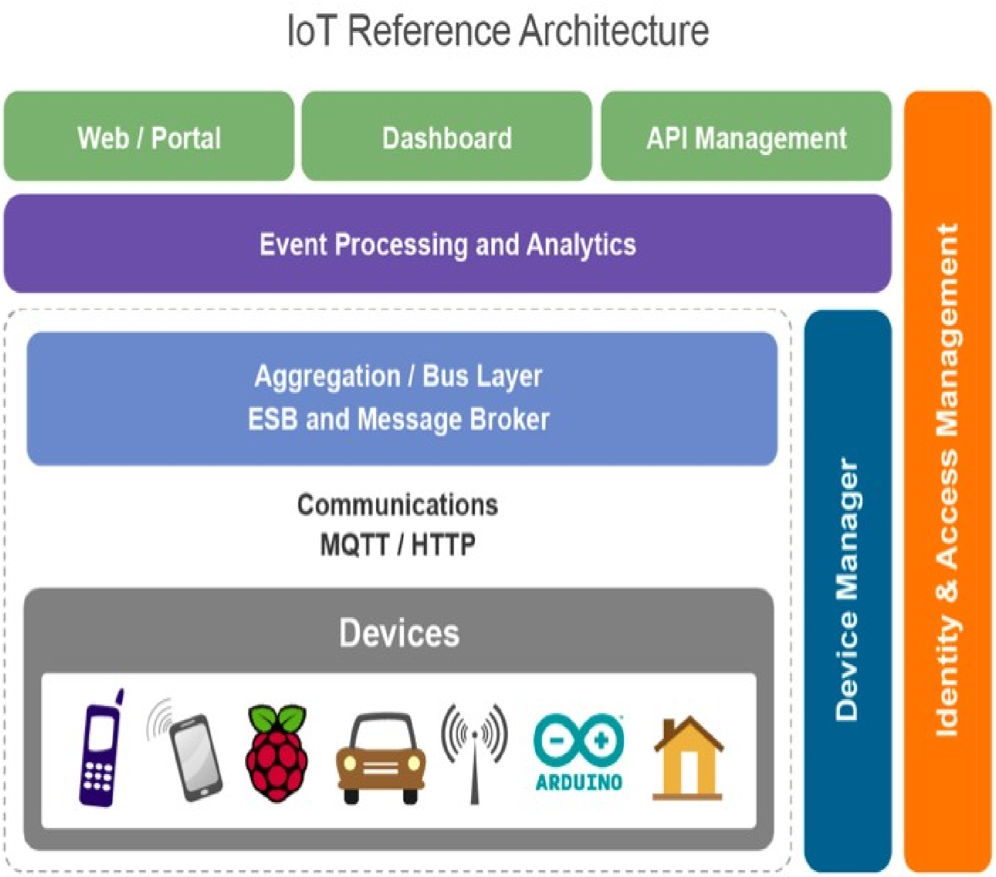
- Extending the current Internet and providing connection, communication, and internetworking between devices and physical objects, or "Things," is a growing trend that is often referred to as the Internet of Things.

- Any time, Any place connectivity for Anyone and Anything!





Basic IoT Architecture



- An IoT platform has basically three building blocks
  - Things
  - Gateway
  - Network and Cloud

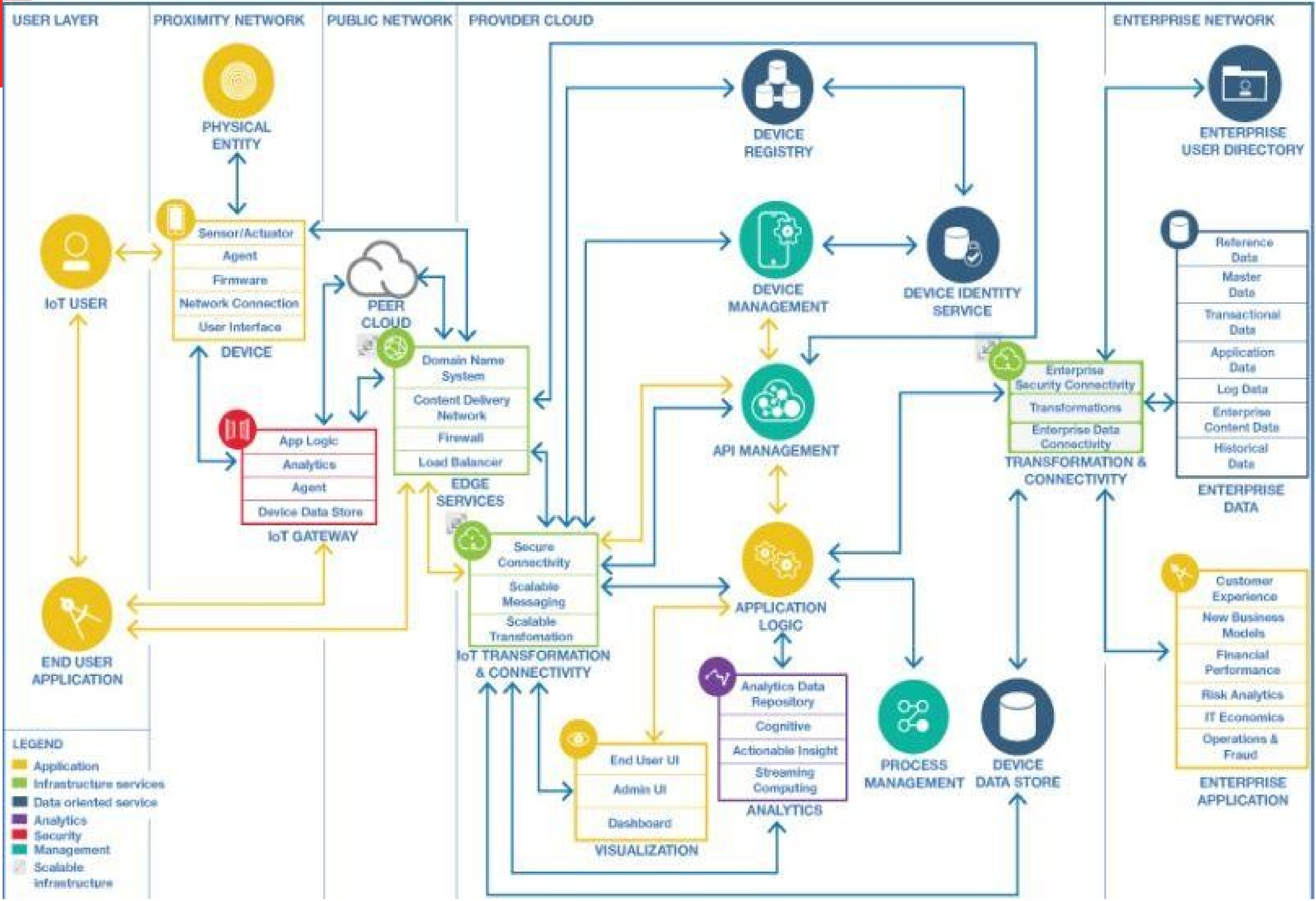
Several Aspects of IoT systems!

- Scalability
- Big Data
- Role of Cloud computing
- Real time
- Highly distributed
- Heterogeneous systems

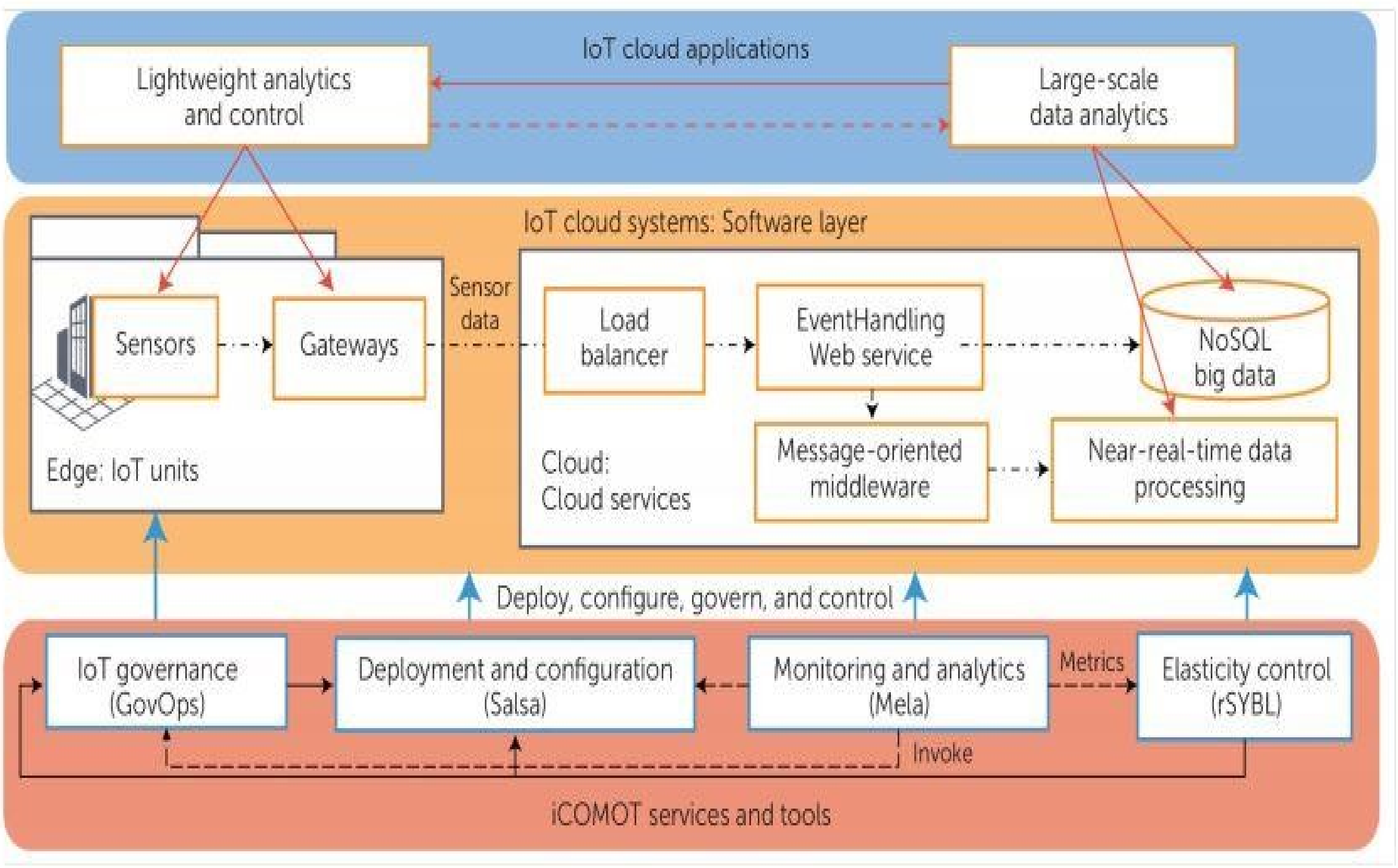
IoT Cloud Systems?

- Recently, there is a wide adoption and deployment of Internet of Things (IoT) infrastructures and systems for various crucial applications, such as logistics, smart cities, and healthcare.
- Thus, for cloud services now act data as computational and data processing platforms as well as management platforms for IoT. From a high-level view, IoT appears to be well-integrated with cloud data centers to establish a uniform infrastructure for IoT Cloud applications

Cloud Components for IoT



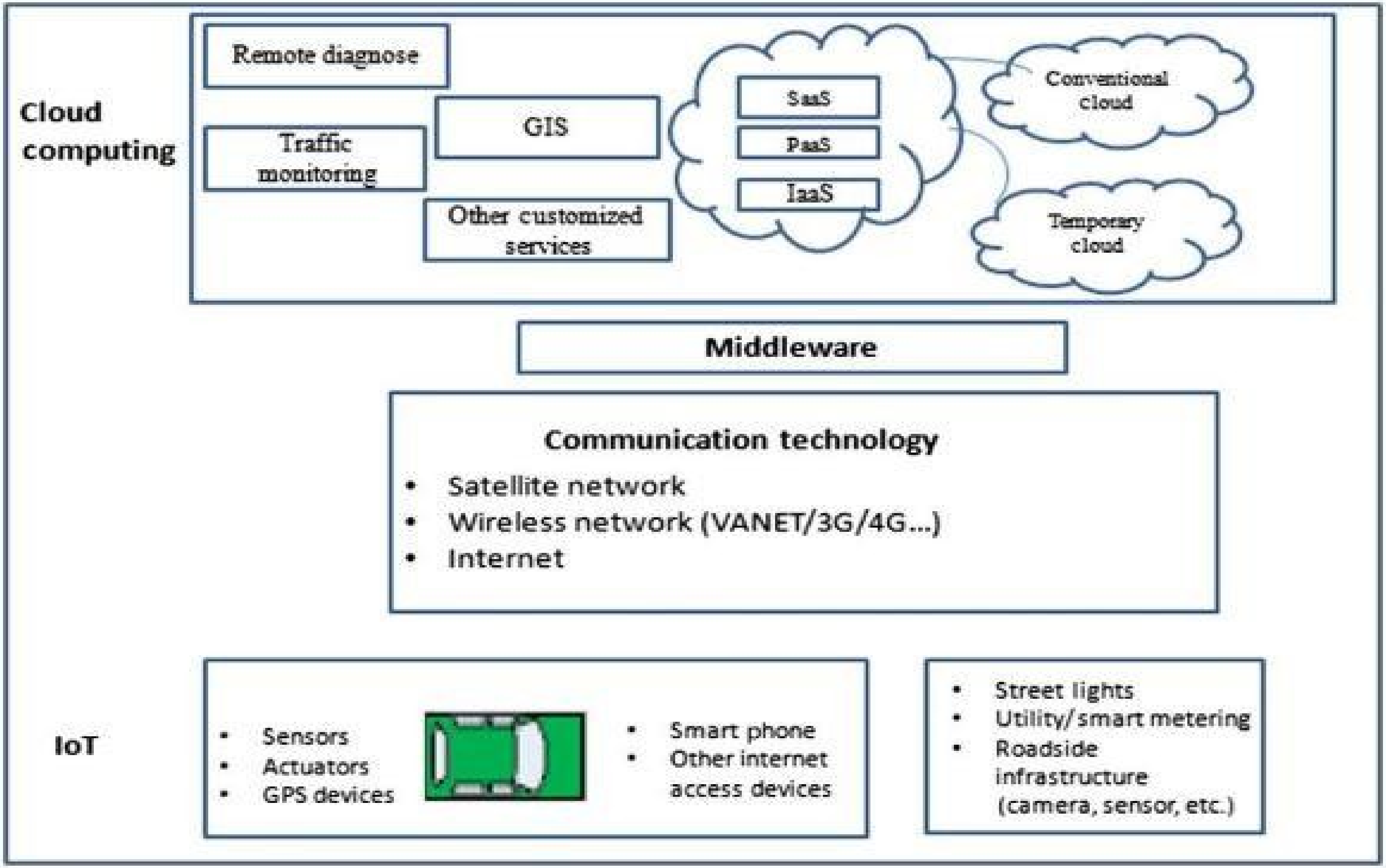
iCOMOT: An IoT Cloud System



Infrastructure, Protocols and Software Platforms for establishing an Internet of Things (IoT) Cloud system

Types	IoT	Clouds	Purpose
Infrastructure machines	Industrial and common gateways (for example, Intel IoT Gateway) and operating system containers (such as Dockers)	Virtual machines and operating system containers	Enable (virtual) machines where software components will be executed
Connectivity protocols	Message Queue Telemetry Transport (MQTT), Constrained Application Protocol (CoAP), HTTP, control area network (CAN) bus	MQTT, Advanced Message Queuing Protocol (AMQP), HTTP, and so on	Enable connectivity among IoT elements and between the IoT part and cloud services
Platform software services	Lightweight data services (such as NiagaraAX/Obix), lightweight complex event processing (CEP) and data fusion, topology description and deployment service (such as TOSCA), and lightweight application containers (such as OSGI and Sedona)	Load balancers (such as HAProxy), message-oriented middleware (MOM) (such as ActiveMQ and Kafka), NoSQL, stream/batch processing (such as Hadoop and Spark), component repositories/ marketplaces, and deployment services (such as TOSCA, HEAT, and Chef)	Enable core platform services for IoT and cloud tasks

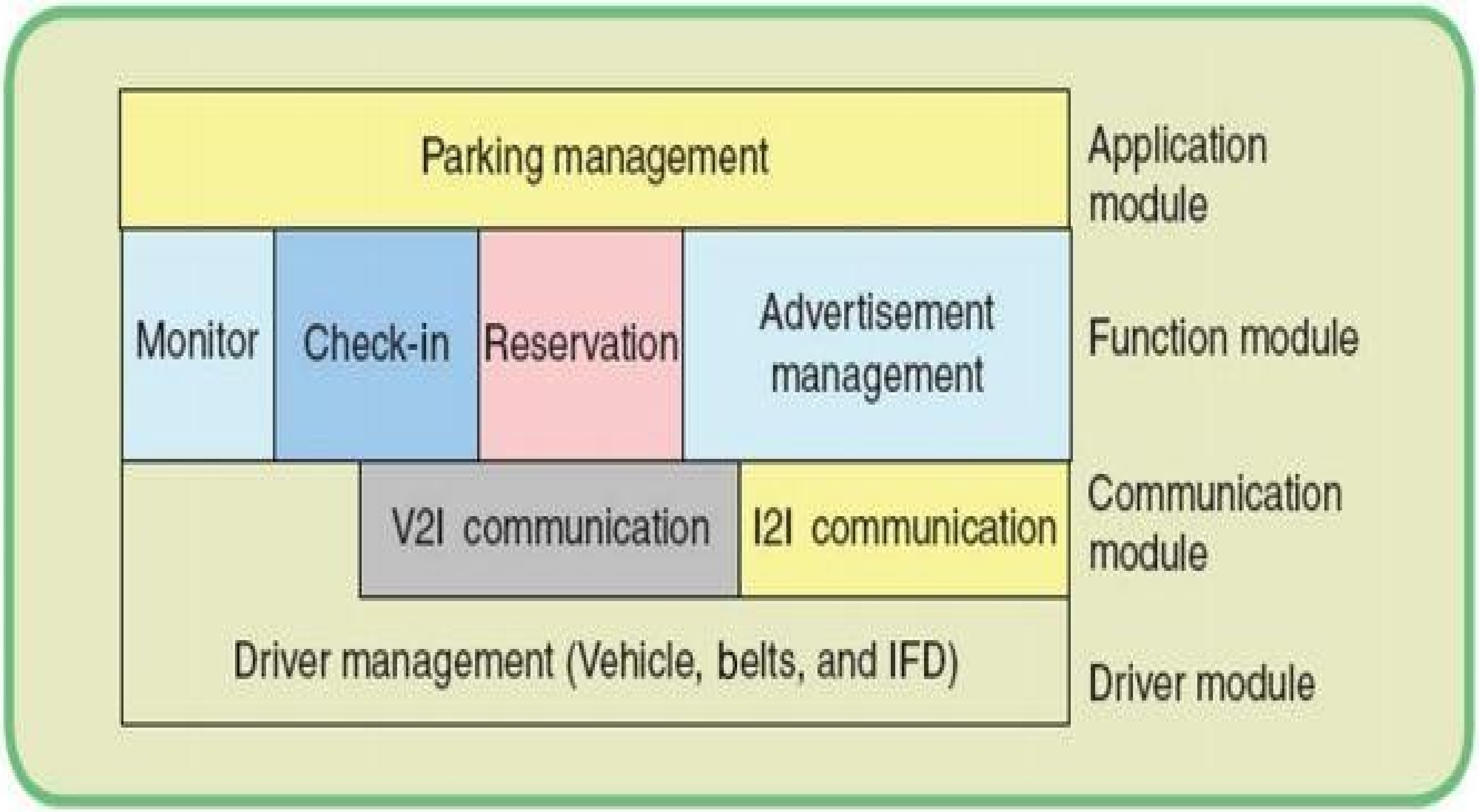
Motivating example: Developing Vehicular Data Cloud Services in the IoT Environment



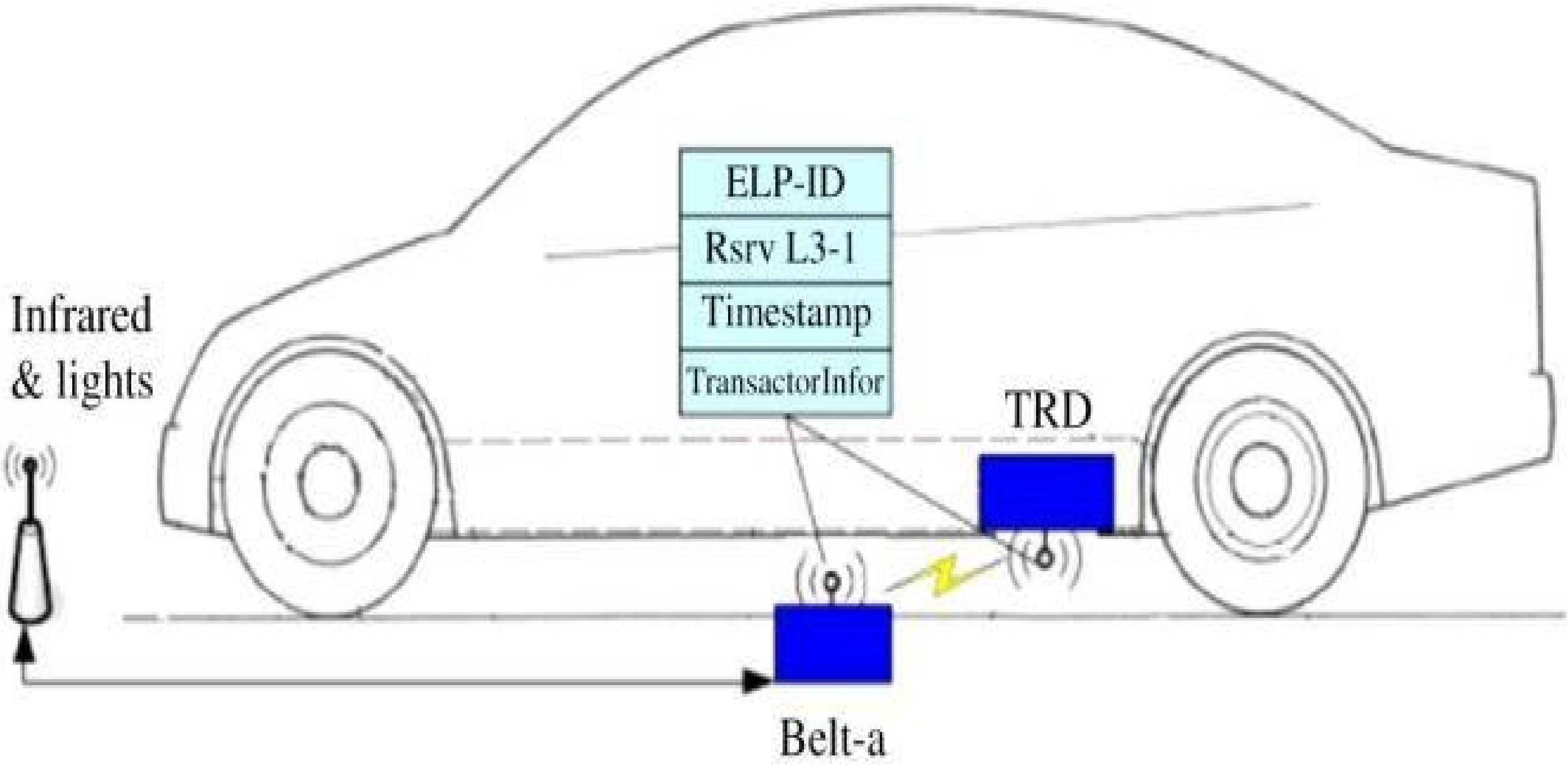
Services for IoT-based Vehicular Data Clouds

New services	Description
Network and Data Processing as a Service, i.e., Infrastructure As A Service (IAAS)	Vehicles provide their networking and data processing capabilities to other vehicles through the cloud
Storage as a Service (SAAS)	Some vehicles may need specific applications that require large amount of storage space. Thus, vehicles that have unused storage space can share their storage space as a cloud-based service
Platform as a Service (PAAS)	As a community, vehicular data clouds offer a variety of cooperative information services such as traffic information, hazardous location warning, lane change warning and parking availability

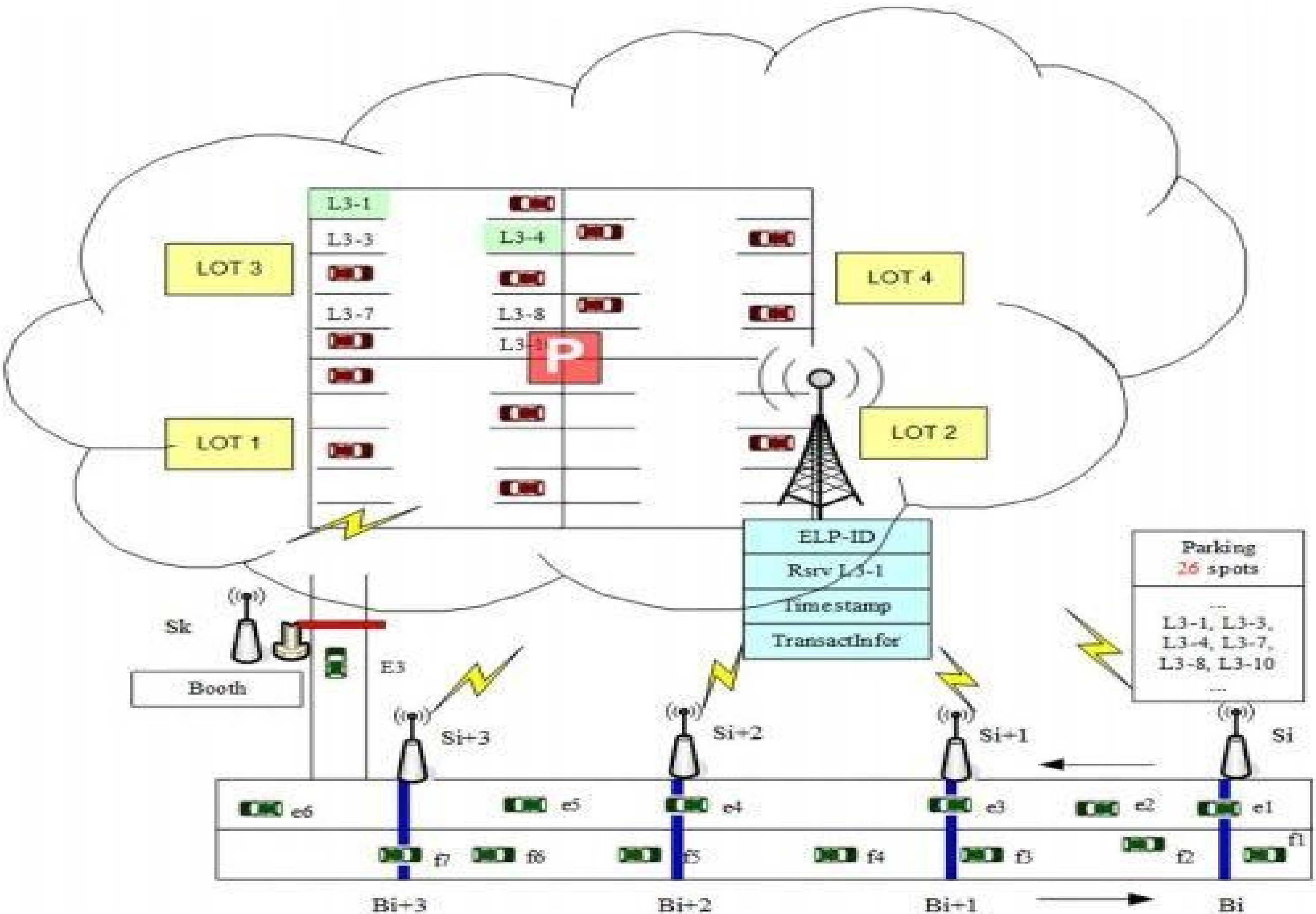
Architecture for Intelligent Parking Cloud service



Vacancy detections by Sensors



Parking cloud service



Summary

- Internet of Things (IoT) is a dynamic and exciting area of IT. Many IoT systems are going to be created over the next few years, covering wide variety of areas, like domestic, commercial, industrial, health and government contexts
- IoT systems have several challenges, namely scale, speed, safety, security and privacy
- Cloud computing platforms offer the potential to use large amounts of resources, both in terms of the storage of data and also in the ability to bring flexible and scalable processing resources to the analysis of data
- IoT Cloud Platform is an enabling paradigm to realize variety of services