Fog Computing

Cloud Computing : Challenges

- Processing of huge data in a datacenter.
- Datacenter may be privately hosted by the organization (private cloud setup) or publicly available by paying rent (public cloud).
- All the necessary information has to be uploaded to the cloud for processing and extracting knowledge from it.

Cloud Computing – Typical Characteristics

- **Dynamic scalability:** Application can handle increasing load by getting more resources.
- **No Infrastructure Management by User:** Infrastructure is managed by cloud provider, not by end-user or application developer.
- **Metered Service:** Pay-as-you-go model. No capital expenditure for public cloud.

Issues with “Cloud-only” Computing

- Communication takes a long time due to human-smartphone interaction.
- Datacenters are centralized, so all the data from different regions can cause congestion in core network.
- Such a task requires very low response time, to prevent further crashes or traffic jam

Fog Computing

- Fog computing, also known as fogging/edge computing, it is a model in which data, processing and applications are concentrated in devices at the network edge rather than existing almost entirely in the cloud.
- The term "Fog Computing" was introduced by the Cisco Systems as new model to ease wireless data transfer to distributed devices in the Internet of Things (IoT) network paradigm
- CISCO’s vision of fog computing is to enable applications on billions of connected devices to run directly at the network edge.
  - Users can develop, manage and run software applications on Cisco framework of networked devices, including hardened routers and switches.
  - Cisco brings the open source Linux and network operating system together in a single networked device

Fog Computing

- Bringing intelligence down from the cloud close to the ground/ end-user.
- Cellular base stations, Network routers, WiFi Gateways will be capable of running applications.
- End devices, like sensors, are able to perform basic data processing.
- Processing close to devices lowers response time, enabling real-time applications.

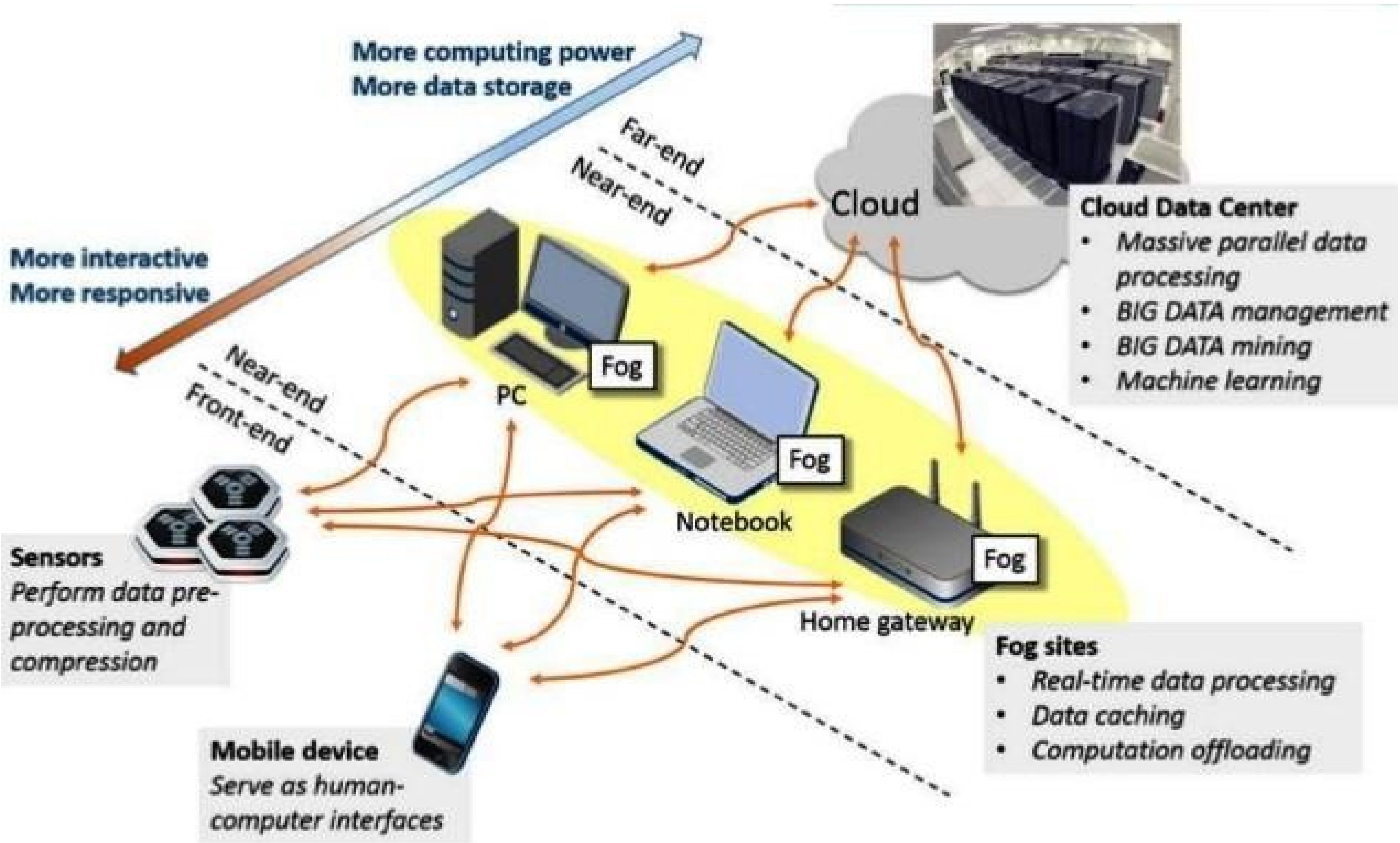
Fog Computing

- Fog computing enables some of transactions and resources at the edge of the cloud, rather than establishing channels for cloud storage and utilization.
- Fog computing reduces the need for bandwidth by not sending every bit of information over cloud channels, and instead aggregating it at certain access points.
- This kind of distributed strategy, may help in lowering cost and improve efficiencies.

Fog Computing - Motivation

- Fog Computing is a paradigm that extends Cloud and its services to the edge of the network
- Fog provides data, compute, storage and application services to the end-user
- Recent developments: Smart Grid, Start Traffic light, Connected Vehicles, Software defined network

Fog Computing



Fog Computing Enablers

- **Virtualization :** Virtual machines can be used in edge devices.
- **Containers:** Reduces the overhead of resource management by using light-weight virtualizations. Example: Docker containers.
- **Service Oriented Architecture:** Service-oriented architecture (SOA) is a style of software design where services are provided to the other components by application components, through a communication protocol over a network.
- **Software Defined Networking:** Software defined networking (SDN) is an approach to using open protocols, such as OpenFlow, to apply globally aware software control at the edges of the network to access network switches and routers that typically would use closed and proprietary firmware.

Fog Computing - not a replacement of Cloud Computing

- Fog/edge devices are there to help the Cloud datacenter to better response time for real-time applications. Handshaking among Fog and Cloud computing is needed.
- Broadly, benefits of Fog computing are:
  - Low latency and location awareness
  - Widespread geographical distribution
  - Mobility
  - Very large number of nodes
  - Predominant role of wireless access
  - Strong presence of streaming and real time applications
  - Heterogeneity

FOG Advantages ?

- Fog can be distinguished from Cloud by its proximity to end-users.
- Dense geographical distribution and its support for mobility.
- It provides low latency, location awareness, and improves quality-of- services (QoS) and real time applications.

Security Issues

- Major security issues are authentication at different levels of gateways as well as in the Fog nodes
- Man-in-the-Middle-Attack
- Privacy Issues
- In case of smart grids, the smart meters installed in the consumer’s home. Each smart meter and smart appliance has an IP address. A malicious user can either tamper with its own smart meter, report false readings, or spoof IP addresses.

Limitations of Cloud Computing

- High capacity(bandwidth) requirement
- Client access link
- High latency
- Security

“Fog” Solution?

- Reduction in data movement across the network resulting in reduced congestion
- Elimination of bottlenecks resulting from centralized computing systems
- Improved security of encrypted data as it stays closer to the end user

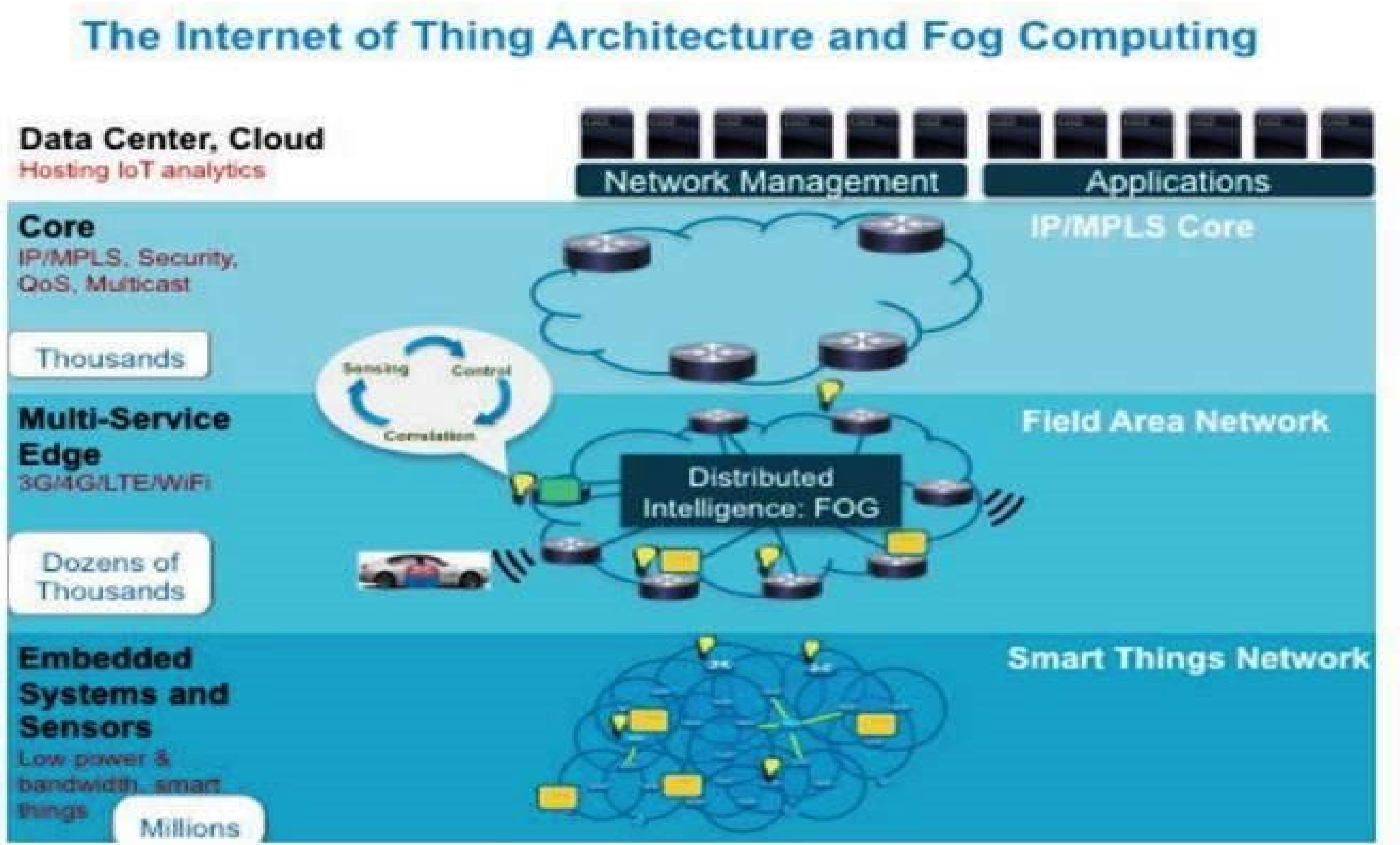
Fog Computing Use-cases

- Emergency Evacuation Systems: Real-time information about currently affected areas of building and exit route planning.
- Natural Disaster Management: Real-time notification about landslides, flash floods to potentially affected areas.
- Large sensor deployments generate a lot of data, which can be pre- processed, summarized and then sent to the cloud to reduce congestion in network.
- Internet of Things (IoT) based big-data applications: Connected Vehicle, Smart Cities, Wireless Sensors and Actuators Networks(WSANs) etc.

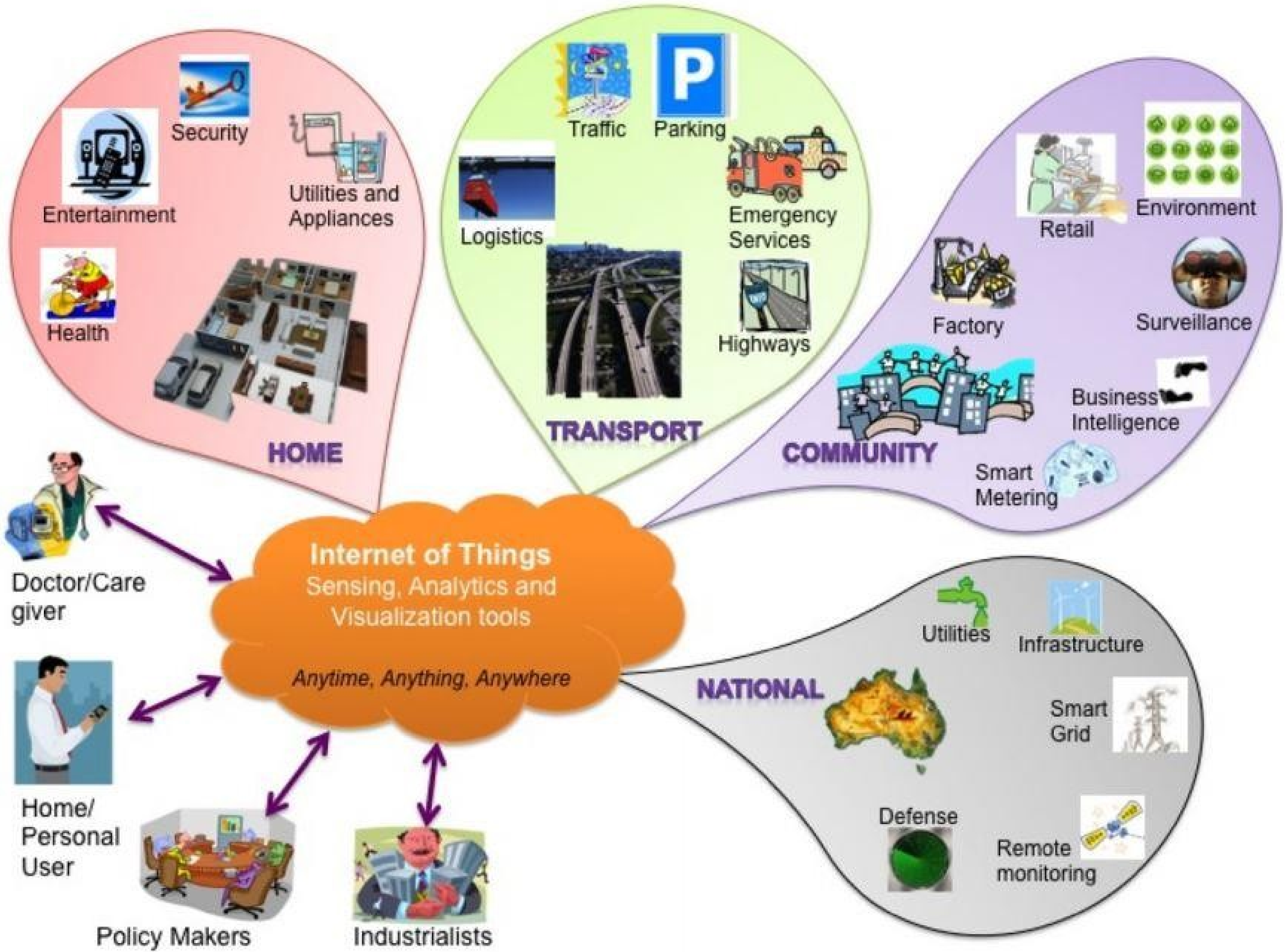
Applicability

- Smart Grids
- Smart Traffic Lights
- Wireless Sensors
- Internet of Things
- Software Defined Network

Fog Computing and IoT (Internet of Things)



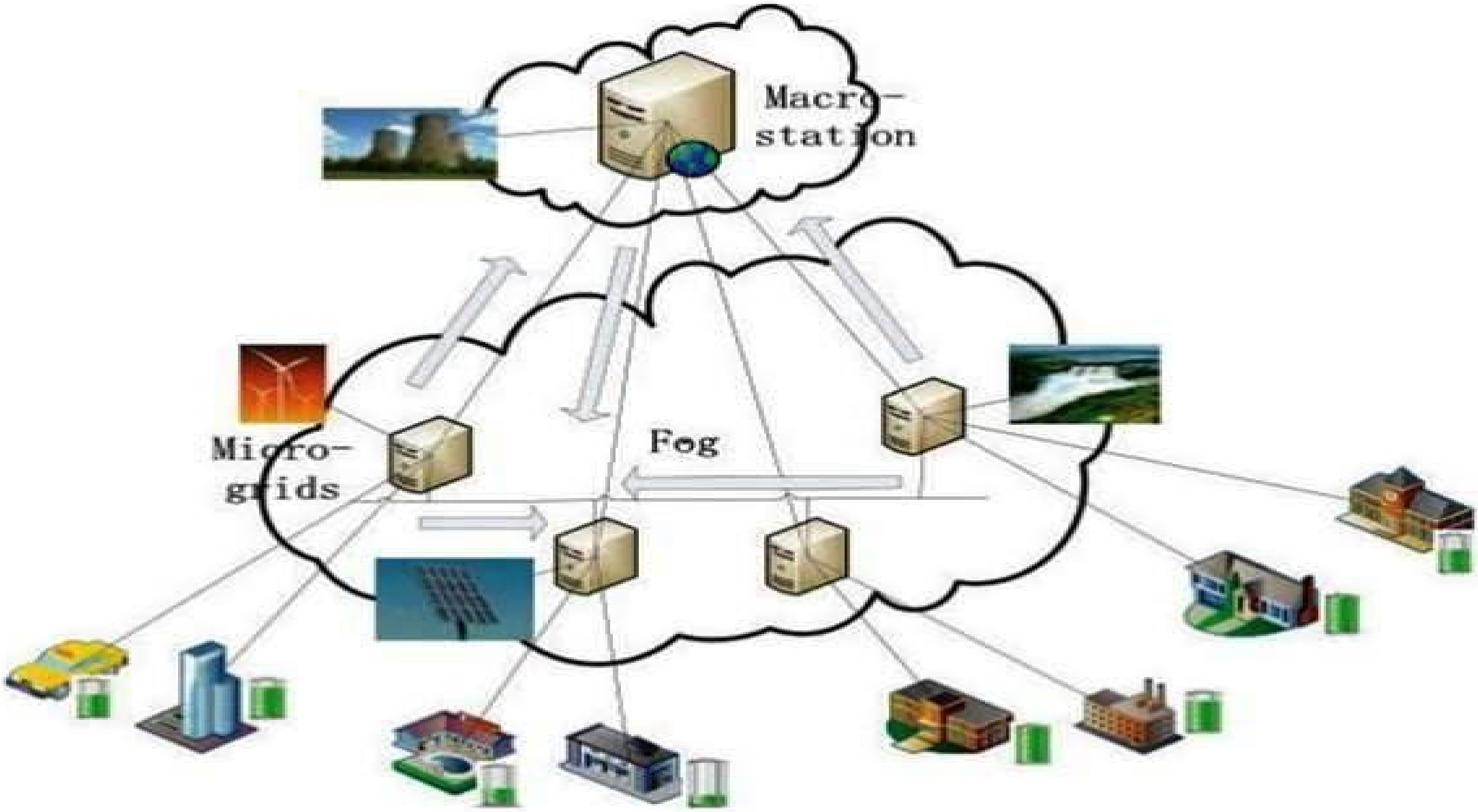
Internet of Things



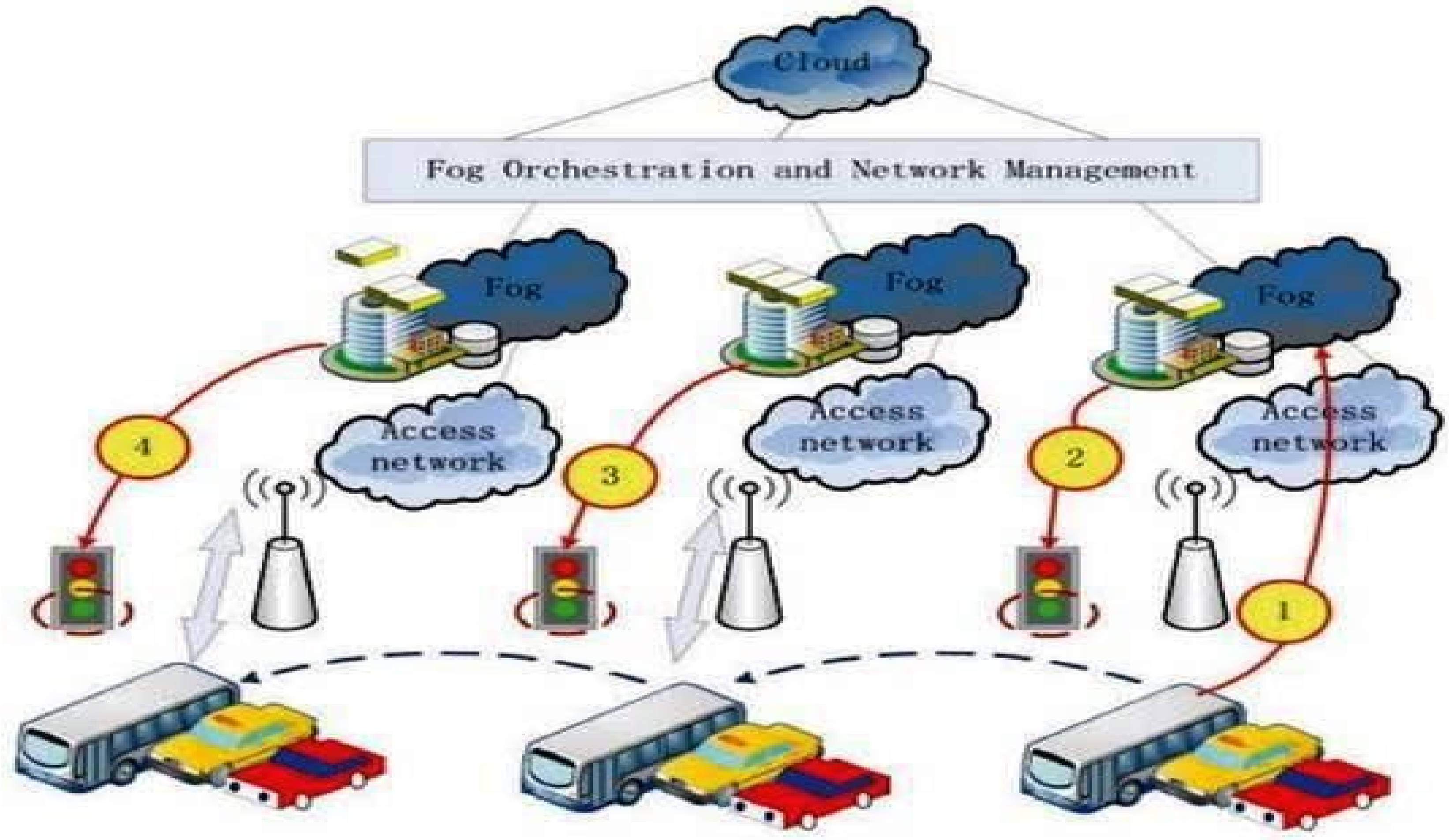
Connected Vehicle (CV)

- The Connected Vehicle deployment displays a rich scenario of connectivity and interactions: cars to cars, cars to access points (Wi-Fi, 3G, LTE, roadside units [RSUs], smart traffic lights), and access points to access points. The Fog has a number of attributes that make it the ideal platform to deliver a rich menu of SCV services in infotainment, safety, traffic support, and analytics: geo-distribution (throughout cities and along roads), mobility and location awareness, low latency, heterogeneity, and support for real-time interactions.

Smart Grid and Fog Computing



Fog computing in Smart Traffic Lights and Connected Vehicles



Fog Challenges

- Fog computing systems suffer from the issue of proper resource allocation among the applications while ensuring the end-to-end latency of the services.
- Resource management of the fog computing network has to be addressed so that the system throughput increases ensuring high availability as well as scalability.
- Security of Applications/Services/Data

Resource Management of Fog network

- Utilization of idle fog nodes for better throughput
- More parallel operations
- Handling load balancing
- Meeting the delay requirements of real-time applications
- Provisioning crash fault-tolerance
- More scalable system

Resource Management – Challenges

- Data may not be available at the executing fog node. Therefore, data fetching is needed from the required sensor or data source.
- The executing node might become unresponsive due to heavy workload, which compromises the latency.
- Choosing a new node in case of micro-service execution migration so that the response time gets reduced.
- Due to unavailability of an executing node, there is a need to migrate the partially processed persistent data to a new node. (State migration)

Resource Management – Challenges (contd...)

- Due to unavailability of an executing node, there is a need to migrate the partially processed persistent data to a new node. (State migration)
- Final result has to transferred to the client or actuator within very less amount of time.
- Deploying application components in different fog computing nodes ensuring latency requirement of the components.
- Multiple applications may collocate in the same fog node. Therefore, the data of one application may get compromised by another application. Data security and integrity of individual applications by resource isolation has to be ensured.

Resource Management – Approaches

- Execution migration to the nearest node from the mobile client.
- Minimizing the carbon footprint for video streaming service in fog computing.
- Emphasis on resource prediction, resource estimation and reservation, advance reservation as well as pricing for new and existing IoT customers.
- Docker as an edge computing platform. Docker may facilitate fast deployment, elasticity and good performance over virtual machine based edge computing platform

Resource Management – Approaches (contd...)

- Resource management based on the fluctuating relinquish probability of the customers, service price, service type and variance of the relinquish probability.
- Studying the base station association, task distribution, and virtual machine placement for cost-efficient fog based medical cyber-physical systems. The problem can be formulated into a mixed-integer non-linear linear program and then they linearize it into a mixed integer linear programming (LP). LP-based two-phase heuristic algorithm has been developed to address the computation complexity.

Fog - Security Issues

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