Computing Paradigms and Architectures for IoT

Cloud computing for IoT

- Big data storage
  - Data center infrastructures
  - Software and system technologies

Google's data center campus
in Eemshaven, Netherlands

Google Cloud

hadoop HDFS

MySQL

PostgreSQL

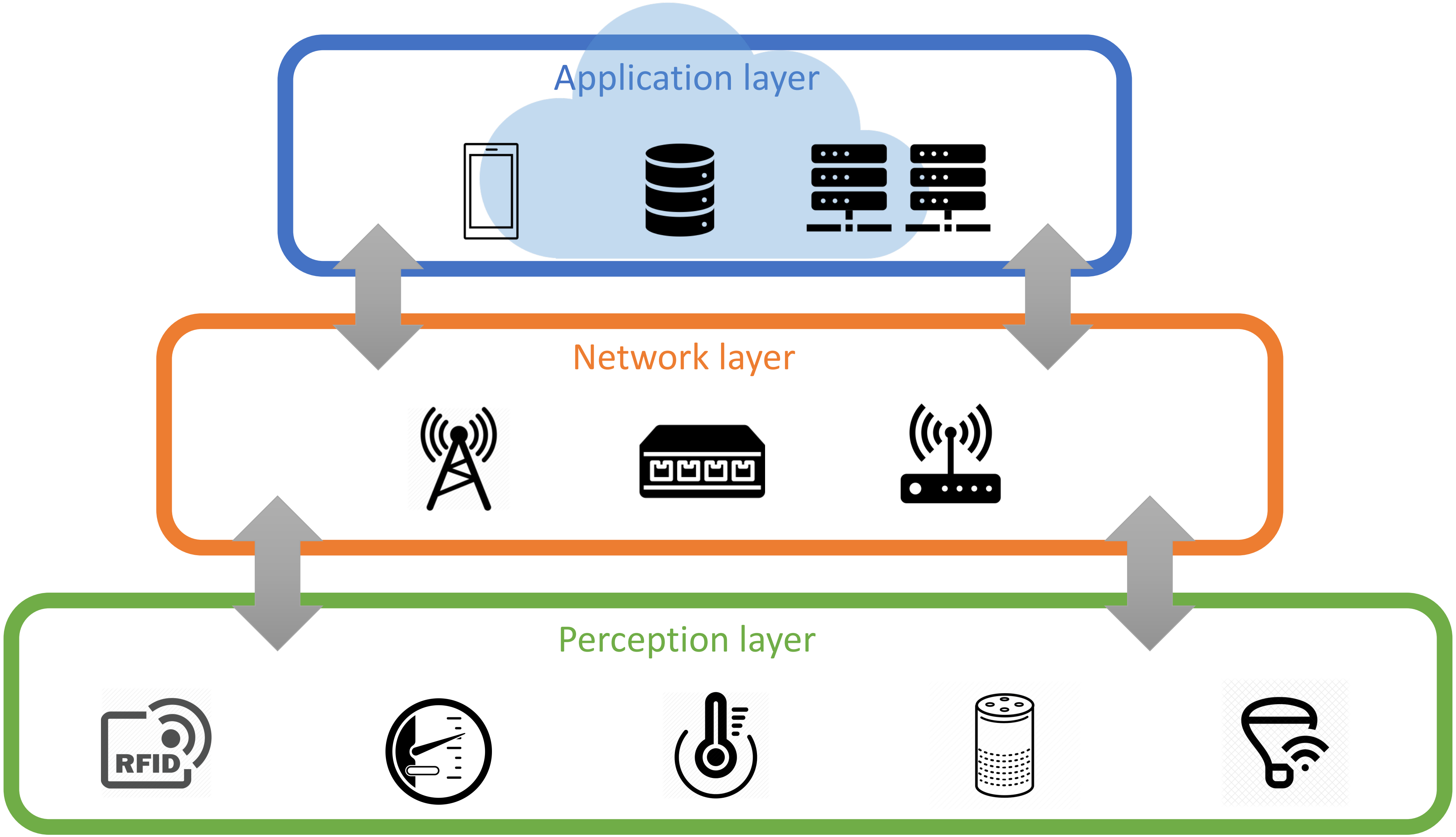
cassandra

RocksDB

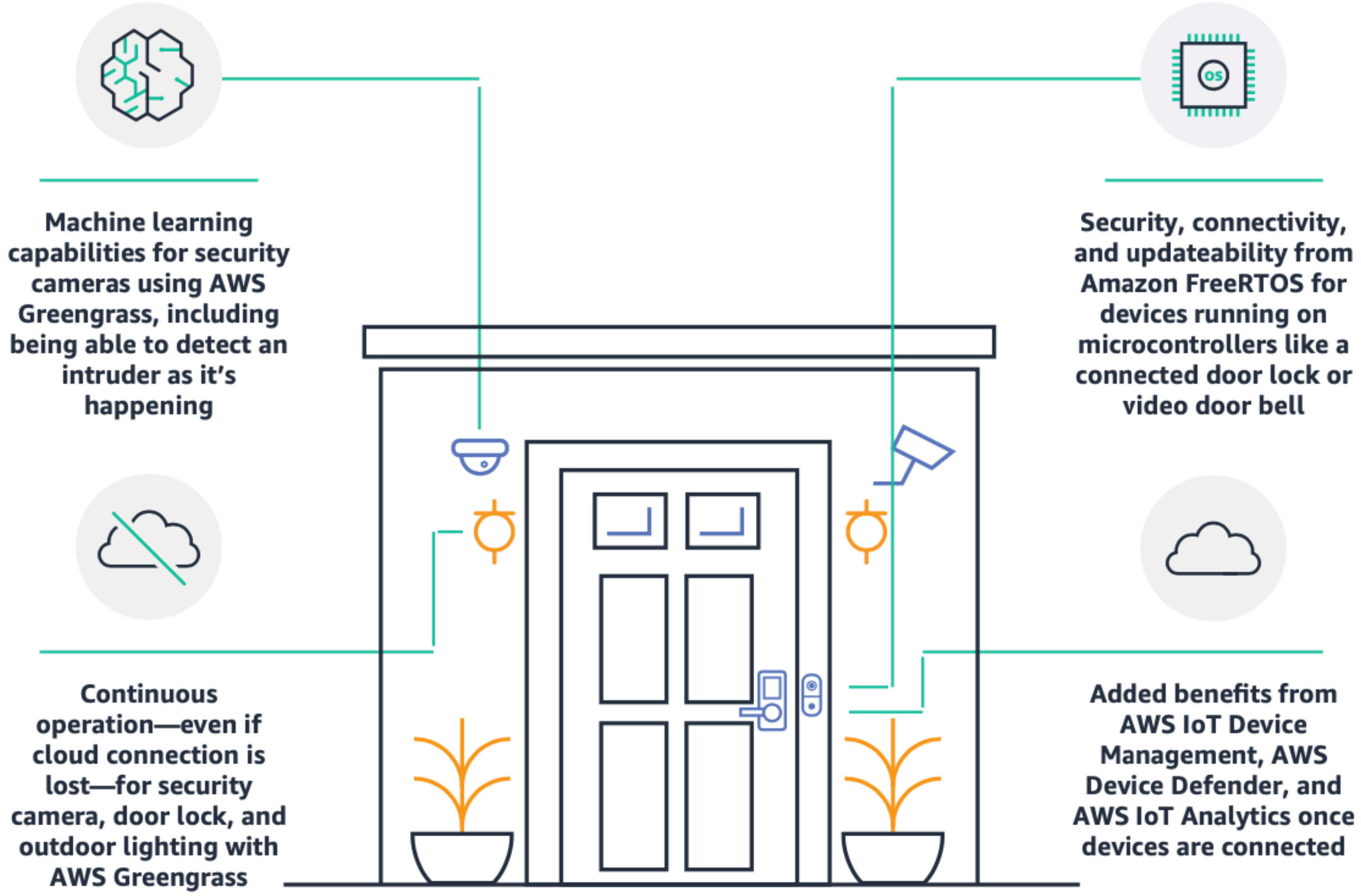
Cloud computing for IoT

- Big data processing

A three-layer architecture

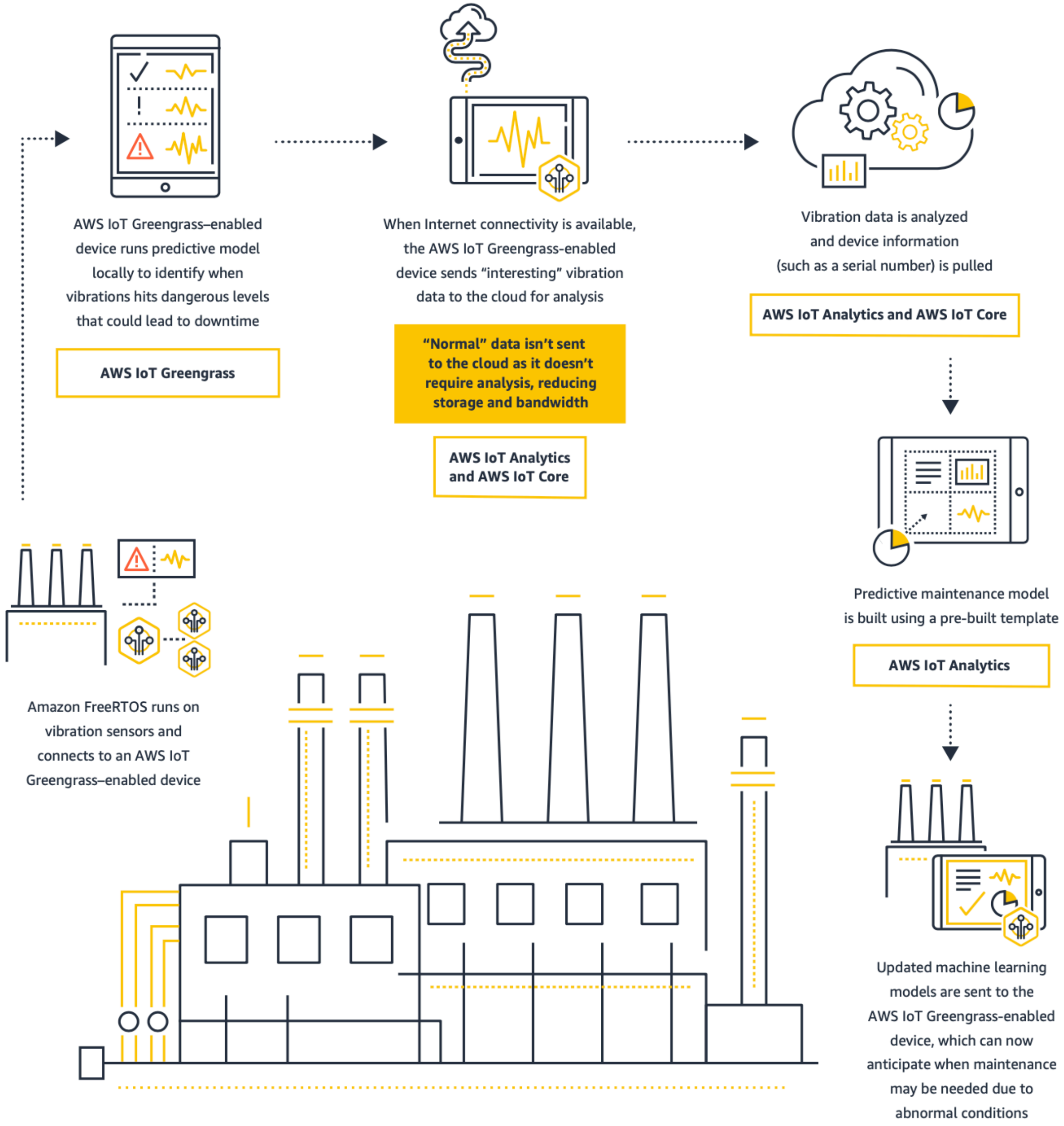


IoT applications on AWS



Home Security & monitoring

https://pages.awscloud.com/rs/112-TZM-766/images/AWS_Connected%20Homes_DES_7.20.18_V3.pdf



Predictive Maintenance

https://d1.awsstatic.com/IoT/Predictive%20Maintenance%20Infographic.pdf

What could be the shortcomings of this cloud-centric approach?

Challenges in cloud-centric IoT architectures

- Latency (< 10 ms for IoT applications)
  - Autonomous driving
  - Industrial monitoring/control systems
  - Gaming, AR/VR
- High bandwidth consumption and poor scalability
  - Billions of IoT devices upload data to cloud
- Geographic distribution
- Intermittent connectivity
  - Vehicles and drones
- Security and privacy

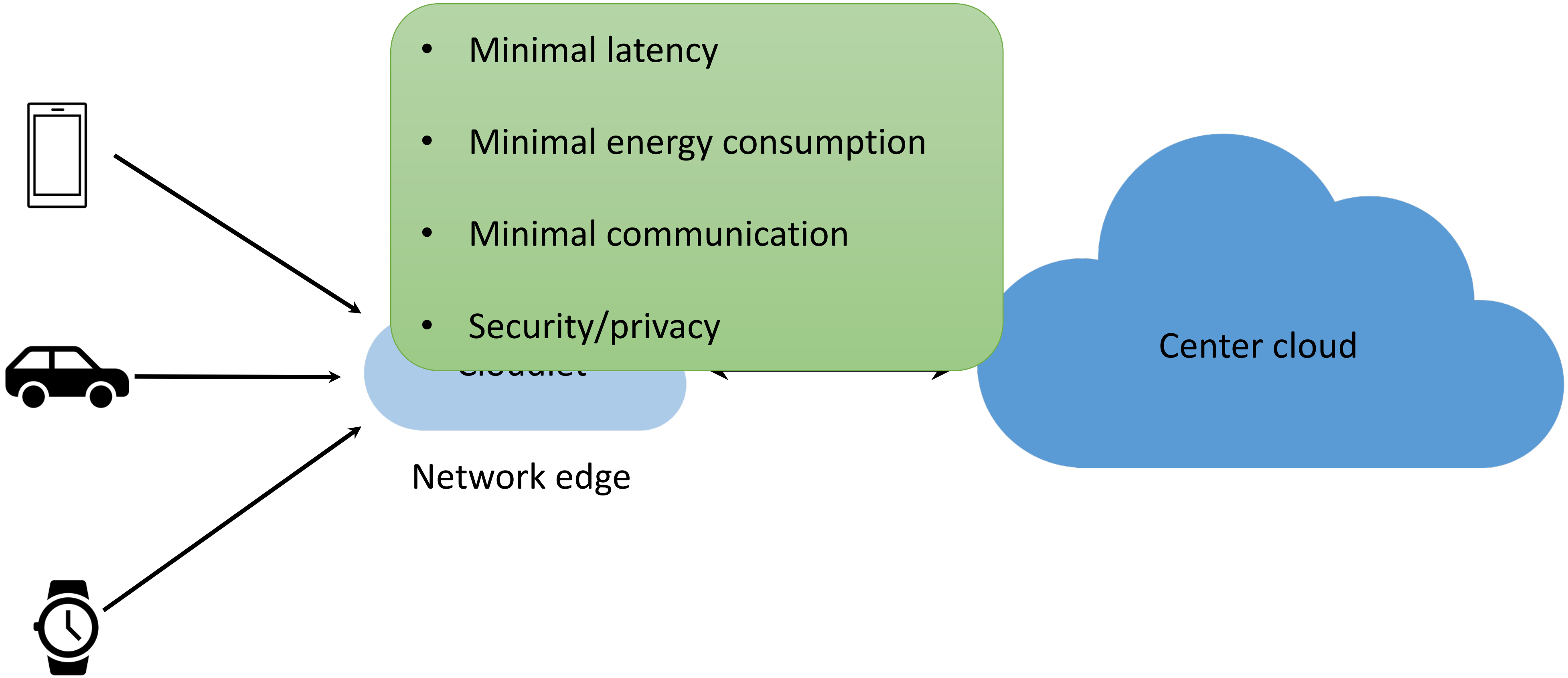
Edge computing paradigm

- Move computation towards the edge of the network

- Move computation closer to data sources (IoT devices)

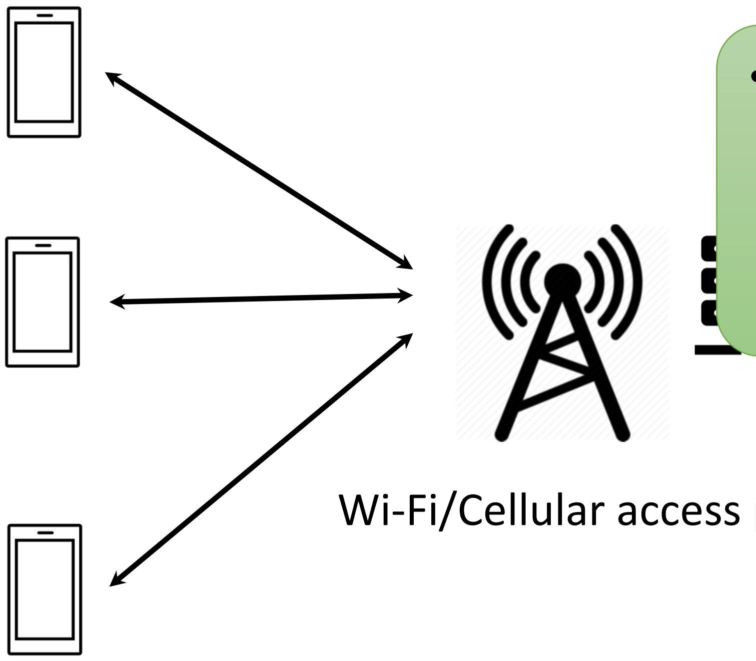
Cloudlet computing

- Cloudlet: small cloud infrastructure located at the network edge
- Offload storage and computation to cloudlet



Mobile edge computing

- IoT devices are connected through network access point
- Devices can collaborate to perform computation tasks



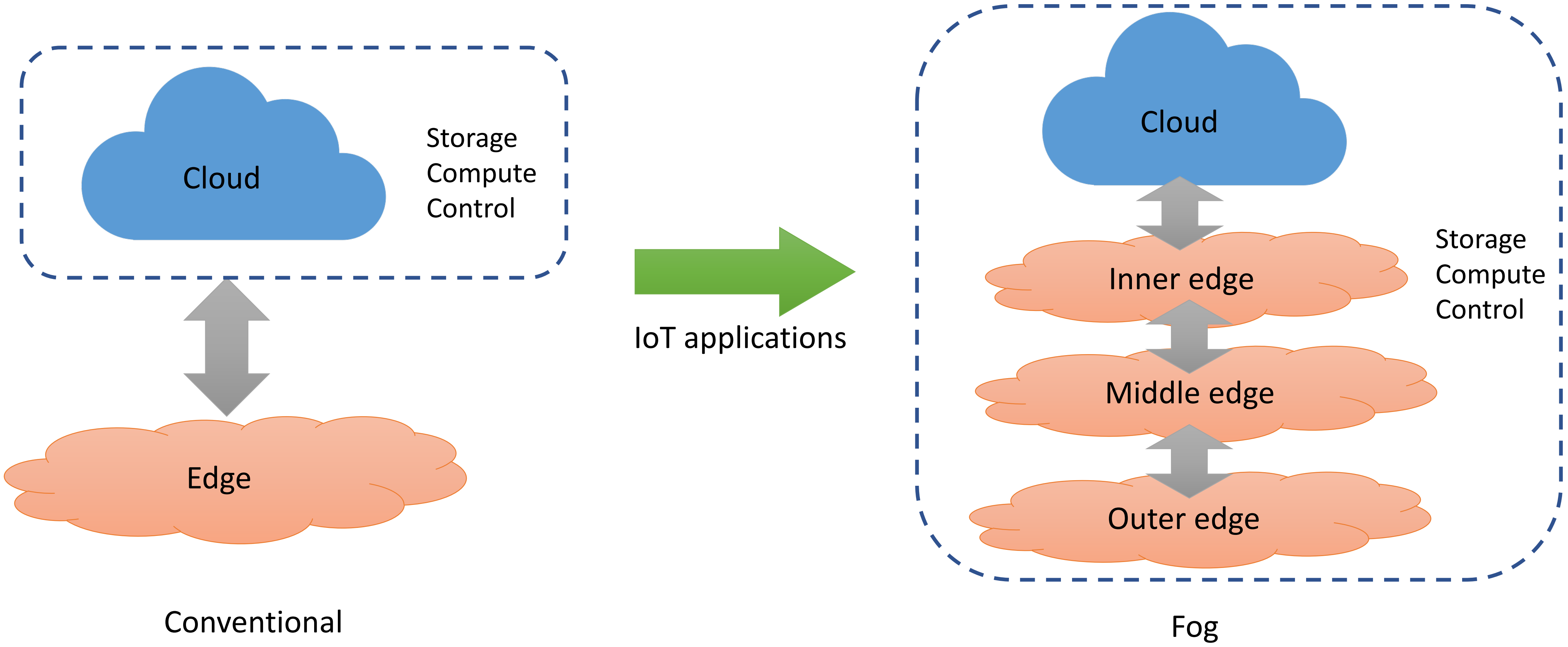
- Device collaboration:
  - Dropout
  - Adversary
  - Scalability
  - Incentive

Edge servers

Wi-Fi/Cellular access point

Fog computing: a unified paradigm

- A continuum of services from cloud to endpoints
  - Further generalizes edge computing up to the cloud



Fog computing: main characteristics

	Cloud	Fog
Location	Centralized data centers	Geo-distributed closer to end users
Size	Cluster of tens of thousands of servers	Flexible: small nodes can perform simple tasks and collaboratively perform complicated ones
Deployment	Sophisticated planning	Ad-hoc
Operation	Fully controlled environment by technical experts	User-determined environment and may not need technical expertise
Application latency	Order of secs	Order of tens of millisecs
Internet connectivity	Required	Intermittent or no
Bandwidth consumption	Scale with users' data	Scale with needed data after filtered by Fog nodes

Fog computing: solving the IoT challenges

- Latency: computing/control close to end users
- Bandwidth requirement: hierarchical processing and selective transmission
- Intermittent connectivity: local Fog system provides uninterrupted real-time services
- Security and privacy: more timely detection of security threats; data can stay at the edge without being revealed to service providers

Fog computing: new business models

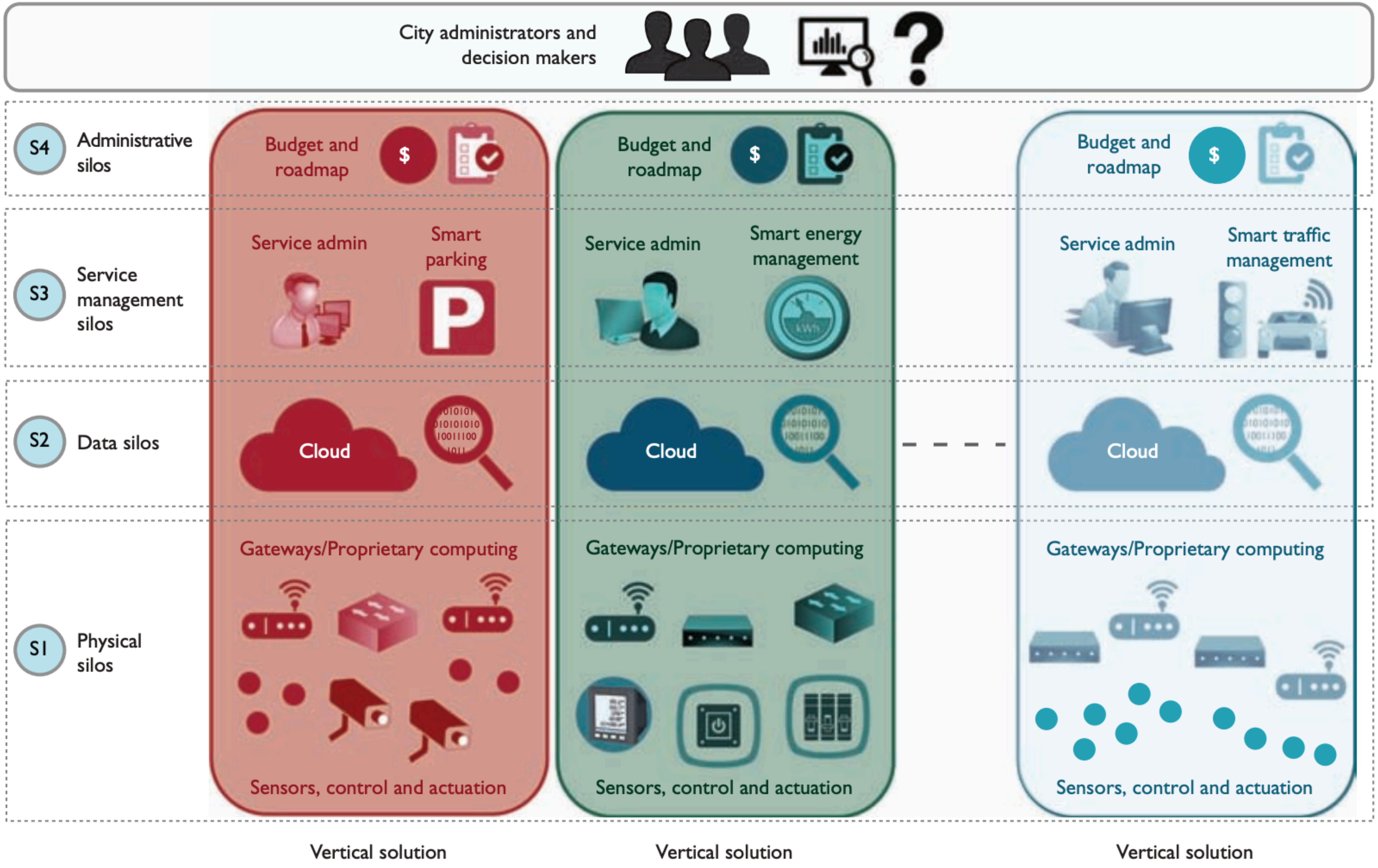
- New applications
  - Autonomous driving
  - Real-time monitoring and analytics
- Fog as a service
  - Not limited to ISPs and big companies
- Integrating network devices, caches, and cloudlets into one type of Fog node

Proof of Concept: Smart city

Fog computing empowered smart city in Barcelona (Cisco 2015)*

[*] Yannuzzi, Marcelo, et al. "A new era for cities with fog computing." *IEEE Internet Computing* 21.2 (2017): 54-67.

Problem: cloud-based solutions create silos



New street cabinets to host general-purposed Fog nodes

- Security
- Distributed analytics
- Monitoring
- Data normalization
- Brokering

Enabling new features

- Autonomous Operation at the Edge

- Data Privacy Policies/Operations

- Physical Constraints
  - Connectivity
  - Latency

- (Real-time) Anomaly Detection

New and improved use cases

	Autonomous Operation (A)	Data Privacy/policy (B)	Physical Constraints (C) Connectivity&delay	Anomaly Detection (D)
Power monitoring/control	😎			😎
Access control/cabinet telemetry	😎			😎
Event-based video		😎	😎	😎
Traffic management	😎	😎	😎	
Connectivity on demand		😎		

System design