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Big Data Analytics in Fog Computing

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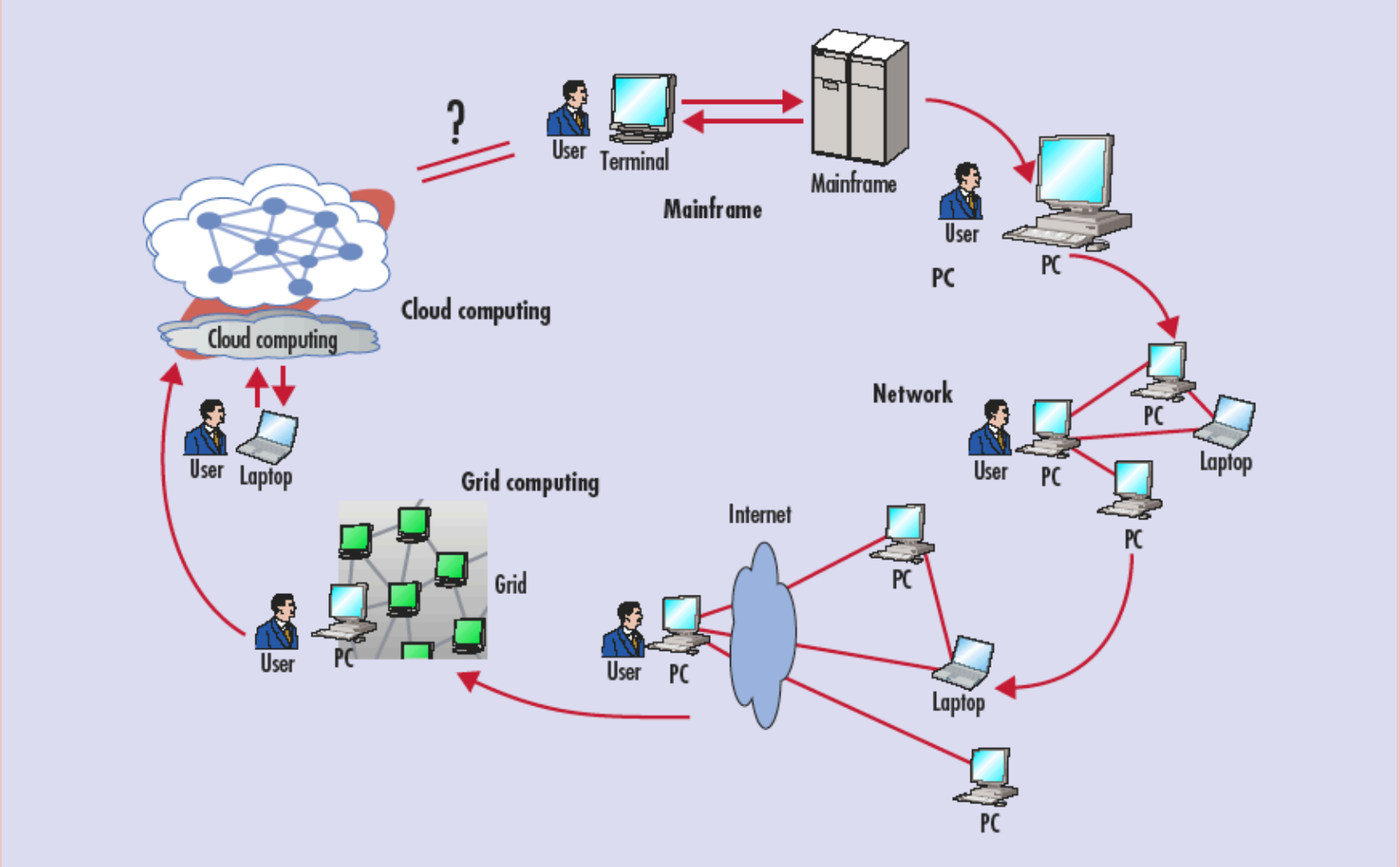
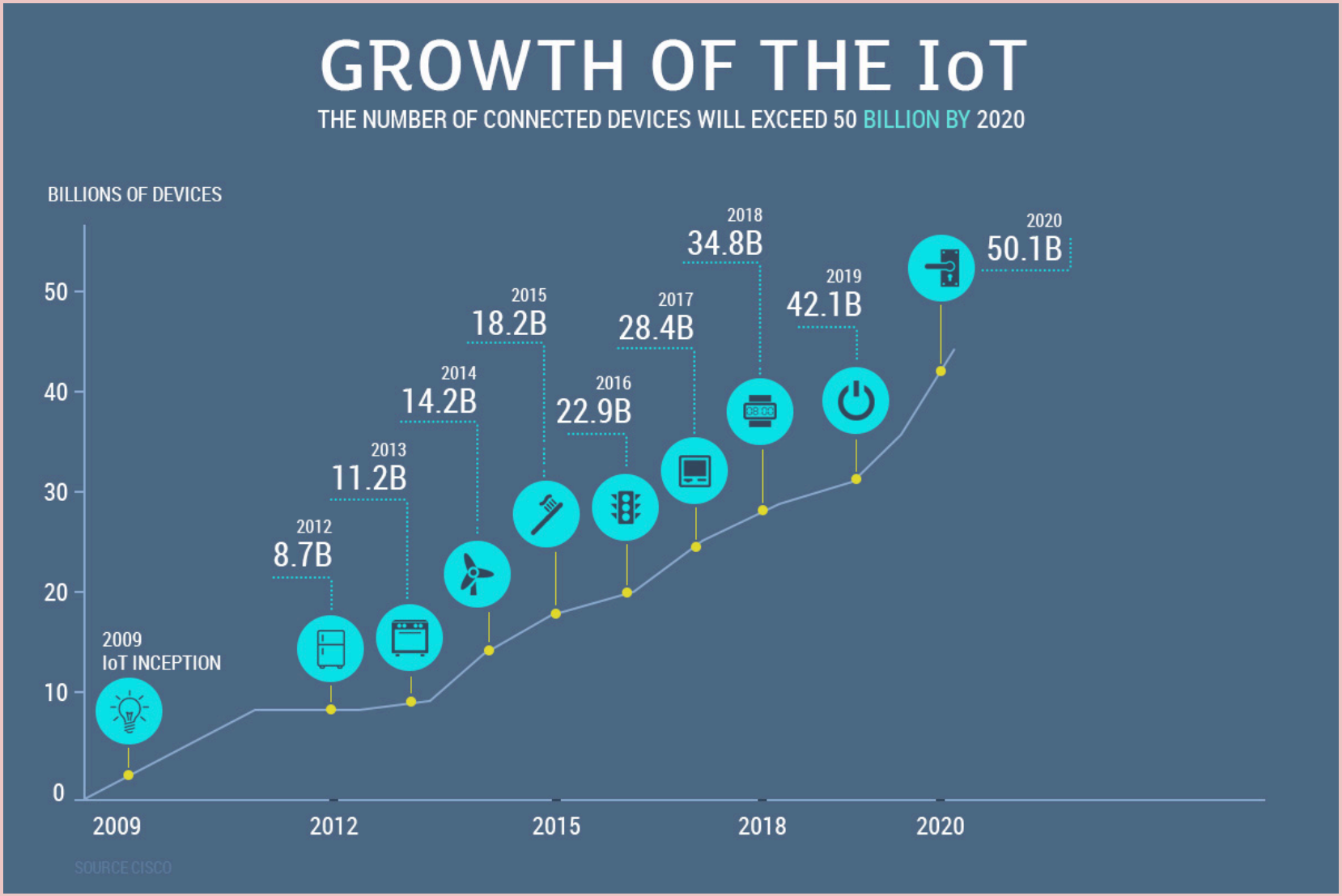
Outline

- Introduction
- Integration of IoTs in Cloud Computing
- Big Data Analytics in Fog Computing
- FOG-Engine: Fog Computing Realization
- Case Study: Smart Nutrition Monitoring System using Fog Computing
- Open Issues and Challenges

Computing Paradigm Shift



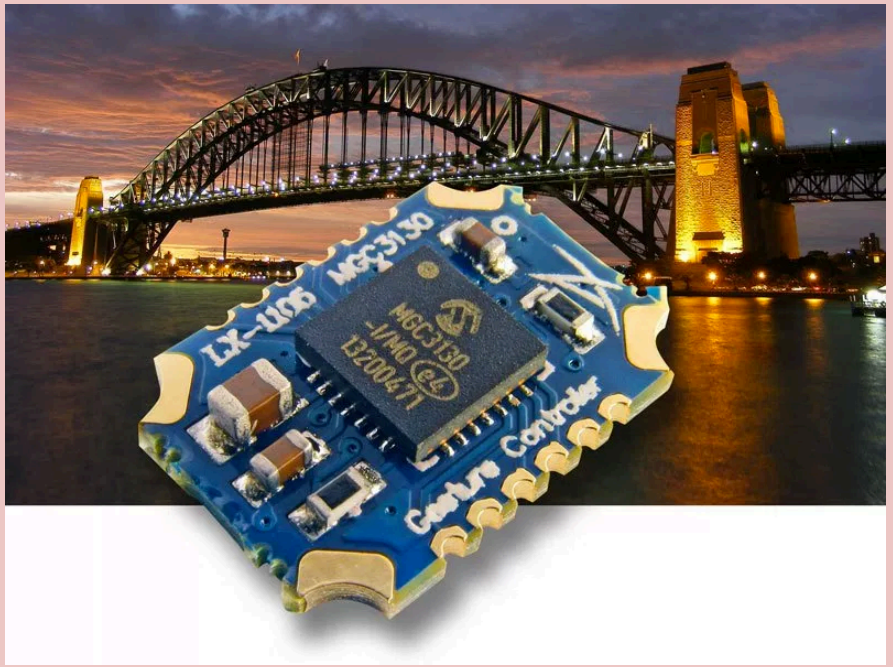
More Connected Devices on the Planet Today Than People



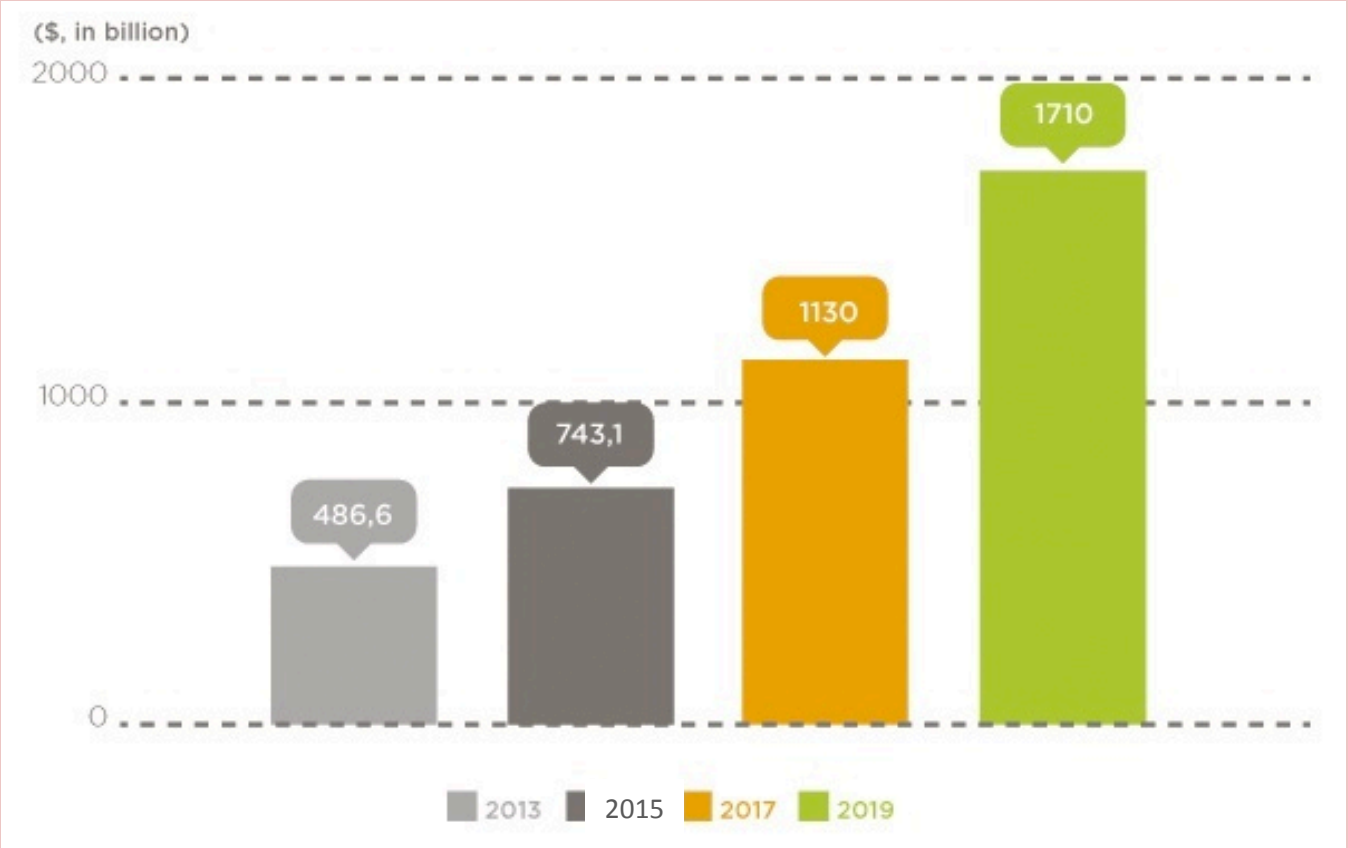
Internet of Things Applications

IoTs in Sydney Harbour Bridge

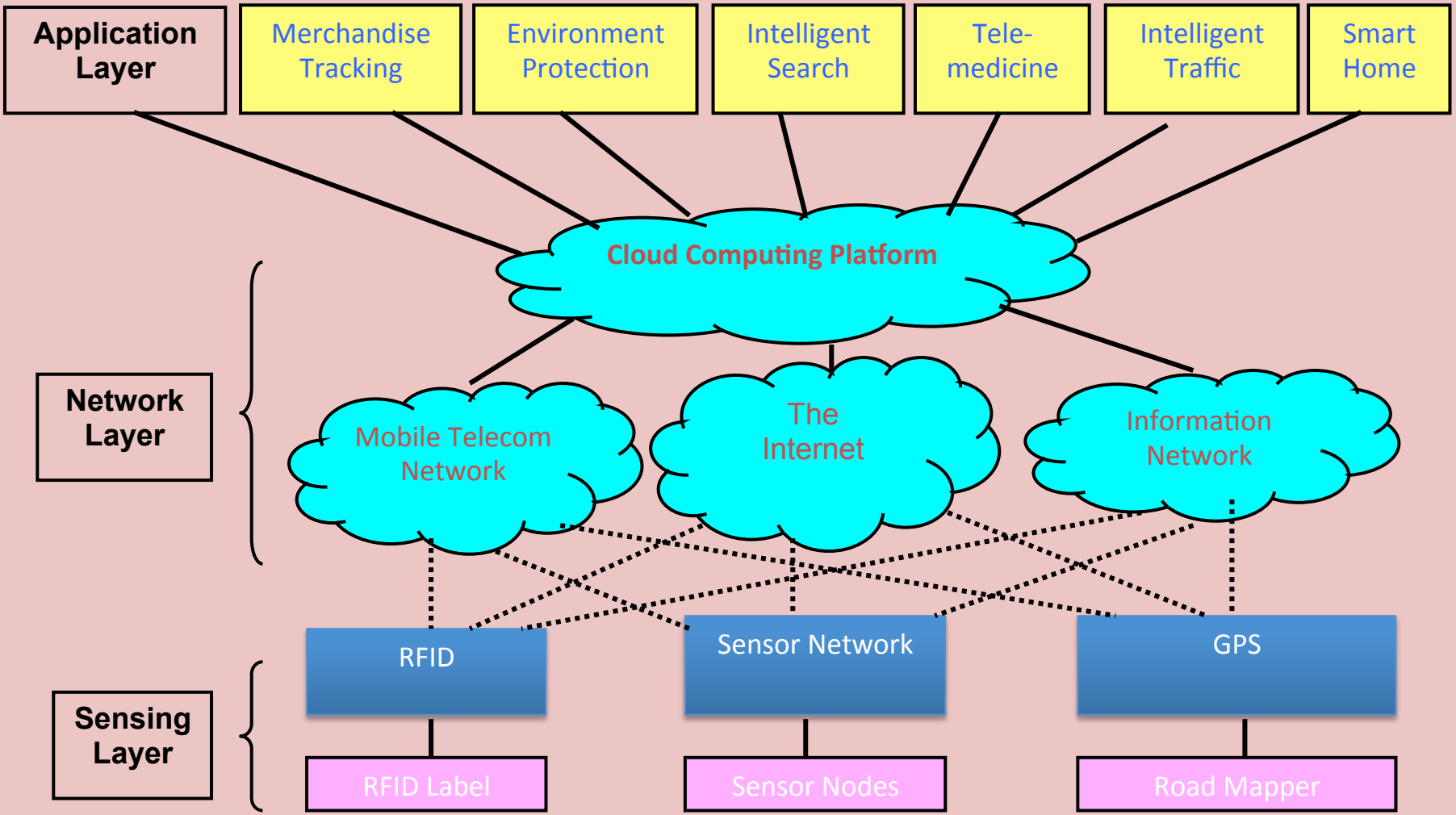
- 1,149m length, 134m height
- 160,000 cars per day
- Moving joints <18cm>
  - 2400 vibration sensors
  - Machine learning for structural monitoring



Global IoT Market



Architecture of the Internet of Things



IoT in Public Clouds

	AWS	Microsoft	IBM	Google	Alibaba
Service	AWS IoT	Azure IoT Hub	IBM Watson IoT	Google IoT	AliCloud IoT
Data Collection	HTTP, WebSockets, MQTT	HTTP, AMQP, MQTT and custom protocols (using protocol gateway project)	MQTT, HTTP	HTTP	HTTP
Security	Link Encryption (TLS), Authentication (SigV4, X.509)	Link Encryption (TLS), Authentication (Per-device with SAS token)	Link Encryption (TLS), Authentication (IBM Cloud SSO), Identity management (LDAP)	Link Encryption (TLS)	Link Encryption (TLS)
Integration	REST APIs	REST APIs	REST and Real-time APIs	REST APIs, gRPC	REST APIs
Data Analytics	Amazon Machine Learning model (Amazon QuickSight)	Stream Analytics, Machine Learning	IBM Bluemix Data Analytics	Cloud Dataflow, BigQuery, Datalab, Dataproc	MaxCompute
Gateway Architecture	Device Gateway (in Cloud)	Azure IoT Gateway (on-premises gateway, beta version)	General Gateway	General Gateway (on-premises)	Cloud Gateway (in Cloud)

Current platforms issues: Not Fully Integrated, No low-latency, and might be Expensive

Service Ecosystem: Fragmented
IoT infrastructure
→ designers need to interact with **many services** from sensors/actuators to data analytic

Cloud: latency
The cloud uses **virtual machines**
→ unnecessary data movement

CLOUD

Data Storage, Analytics

Network: latency, bandwidth and cost
- Large geographical distance→ **Higher Latency**
- The aggregated **b/w** of sensors >> network b/w
- Big Data is heavy to move→ Higher **Cost and Latency**

Raw data

Raw data: the size can be **huge** (e.g. camera)

Network & Internet Infrastructure

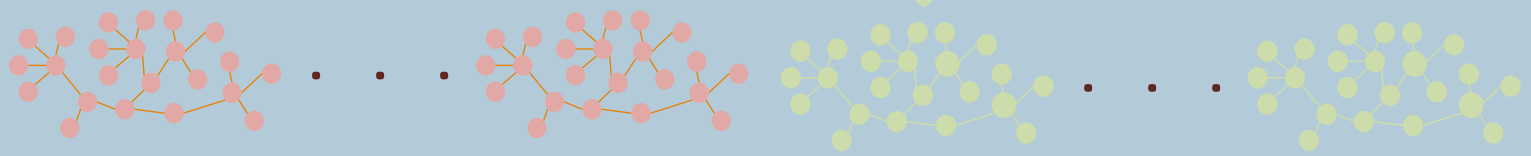
IoTs

Raw data

Big Data Flow

Raw Data

Feedback



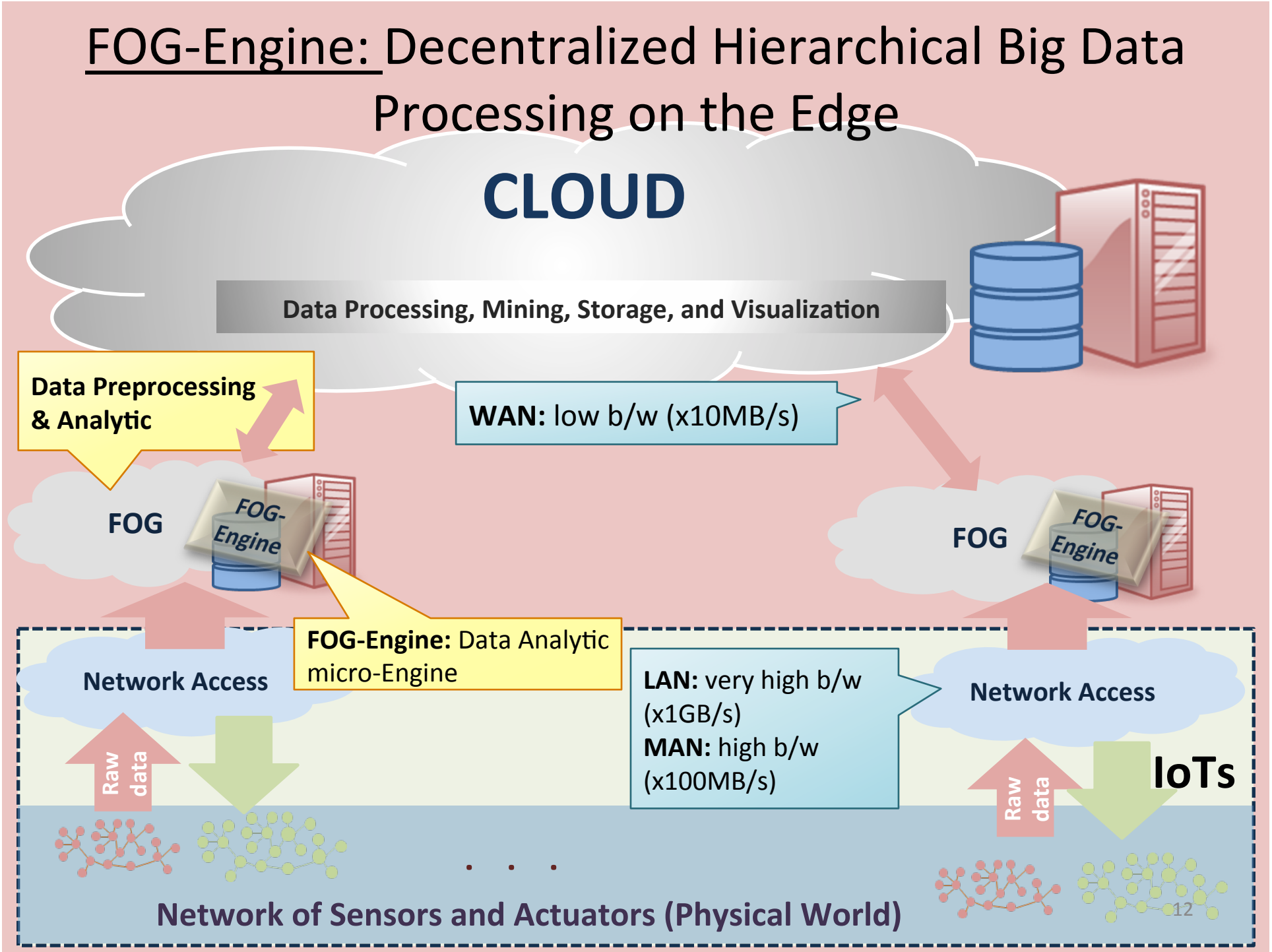
Network of Sensors and Actuators (Physical World)

CYBER-PHYSICAL SYSTEM

Fog Computing

- **The Fog**
  - extends the cloud computing paradigm to the edge of the network,
  - enables a new breed of applications and services
  - an appropriate solution for the applications and services that fold under the umbrella of the IoTs.
- **Benefits**
  - low latency
  - location awareness
  - widespread geographical distribution
  - mobility support
  - the strong presence of streaming and real-time applications
  - heterogeneity

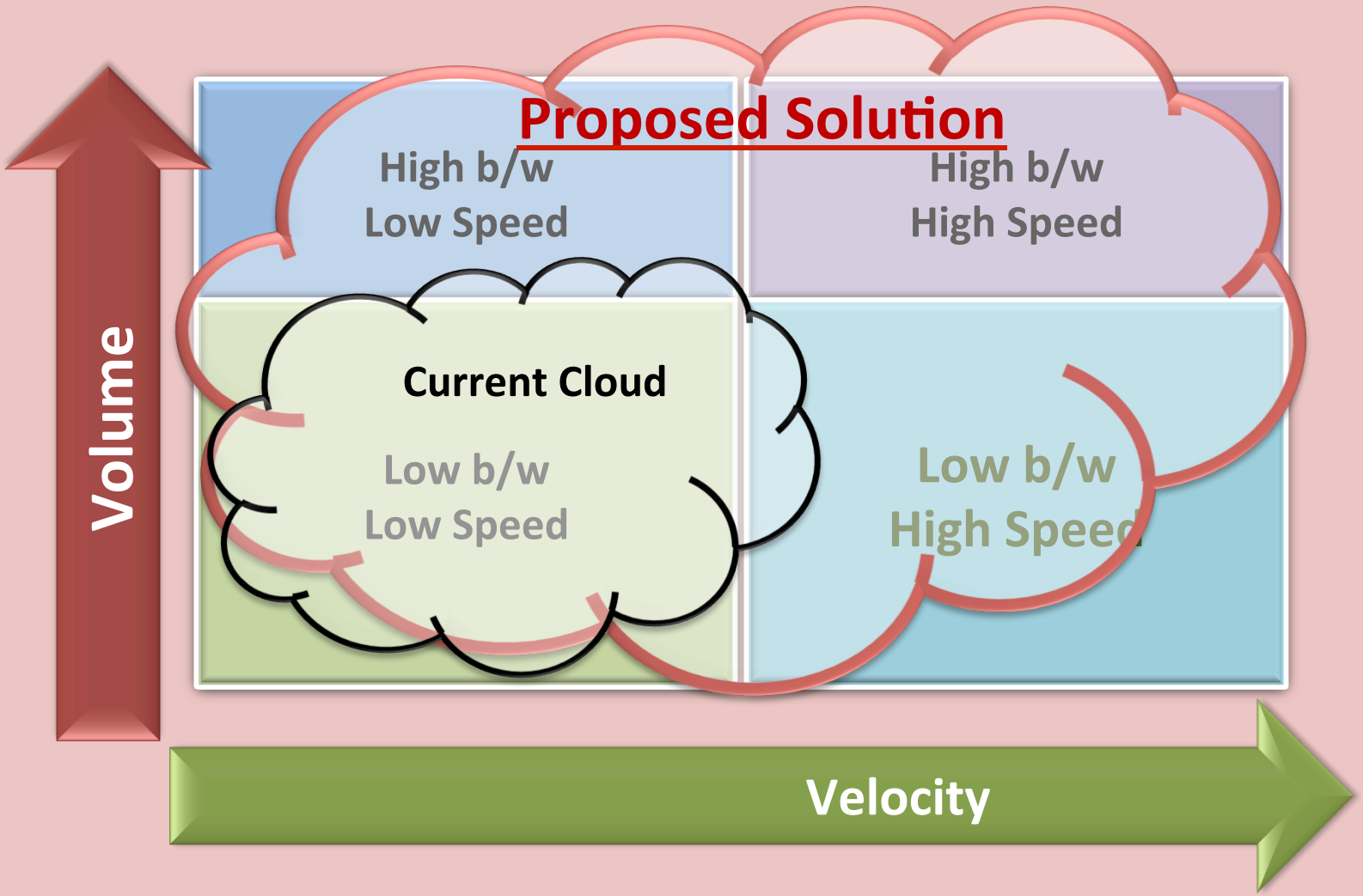
FOG-Engine: Decentralized Hierarchical Big Data Processing on the Edge



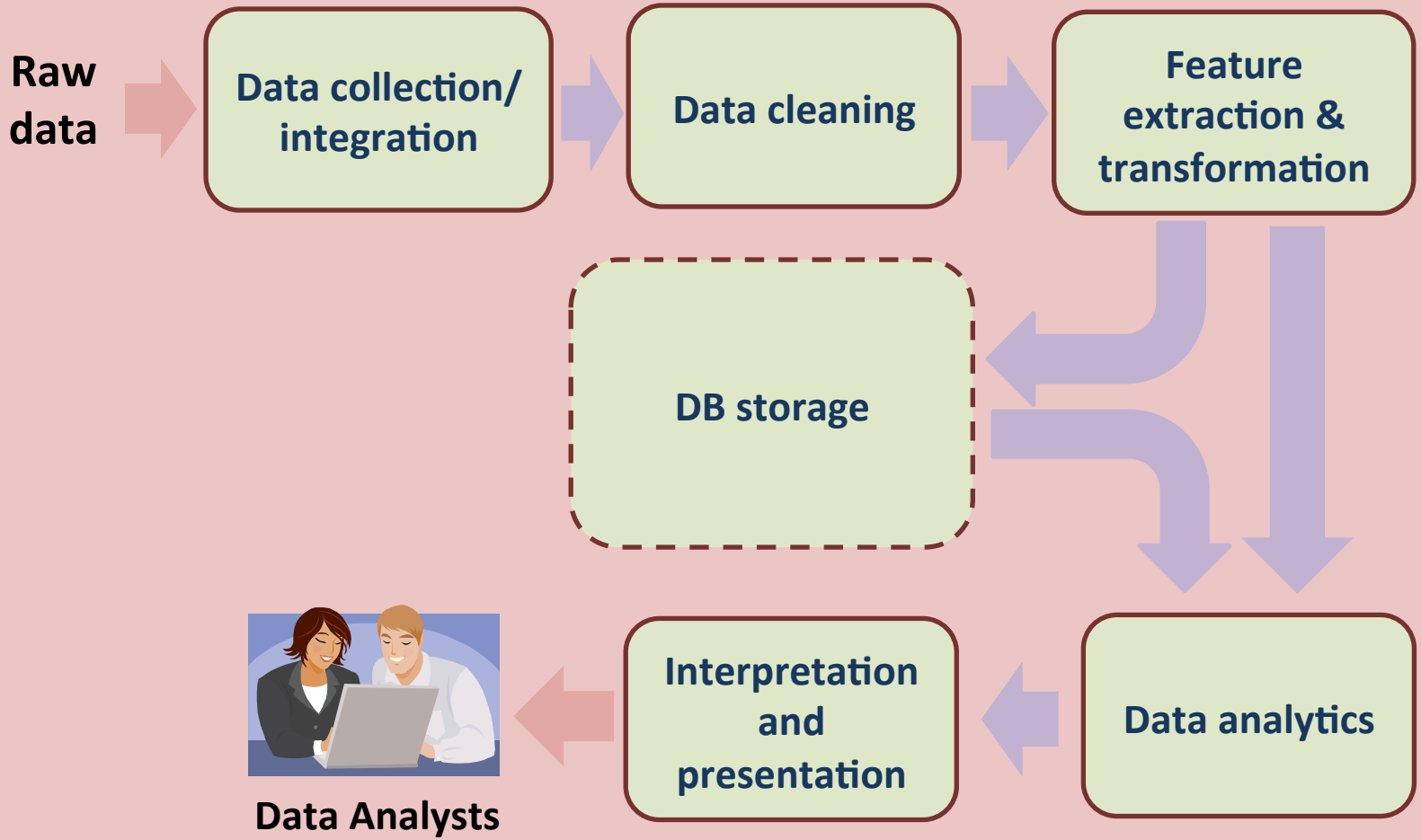
FOG-Engine vs. Cloud

Characteristics	FOG-Engine	Cloud platform
Processing hierarchy	Local data analytics	Global data analytics
Processing fashion	In-stream processing	Batch processing
Computing power	GFLOPS	TFLOPS
Network Latency	Miliseconds	Seconds
Data storage	Gigabytes	Infinite
Data lifetime	Hours/Days	Infinite
Fault-tolerance	High	High
Processing resources	Heterogeneous (e.g. CPU, FPGA)	Homogeneous (Data center)
Versatility	Only exists on demand	Intangible servers
Provisioning	Limited by the number of FOG-engines in the vicinity	Infinite, with latency
Mobility of nodes	May be mobile (e.g. in the car)	None

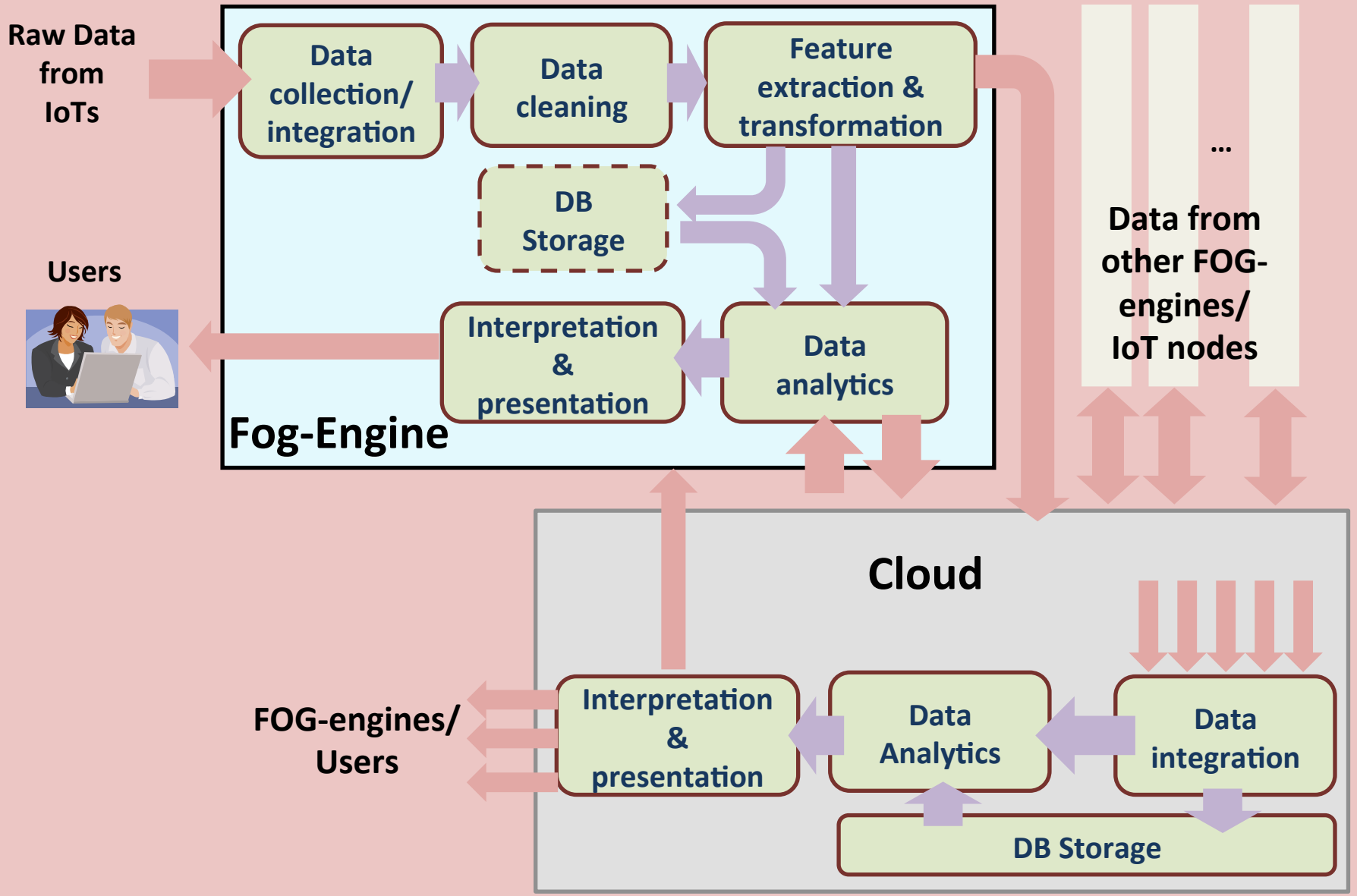
How to Realize Big Data's Vs: Velocity, Volume, …



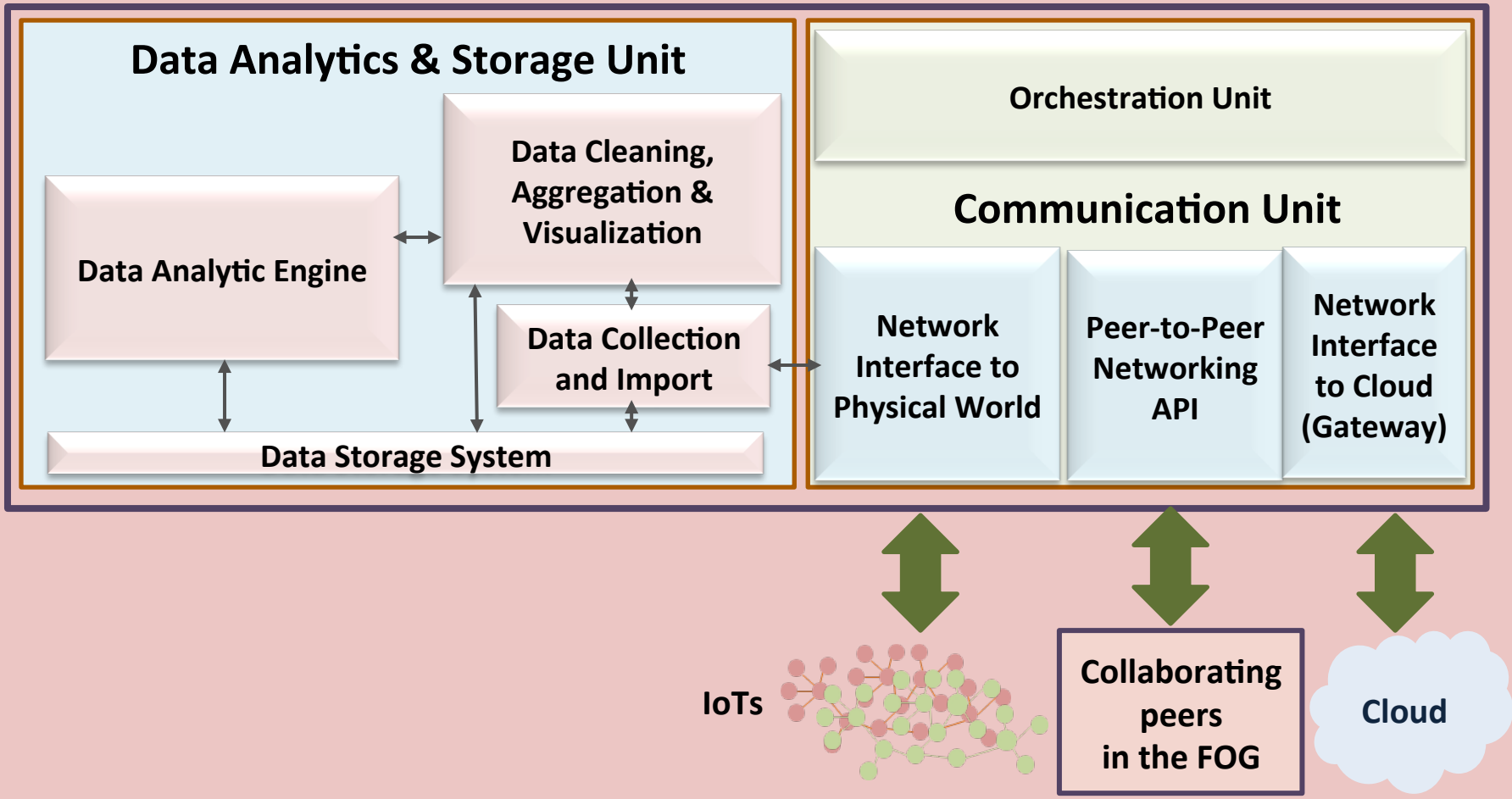
A Typical Data Analytics Flow



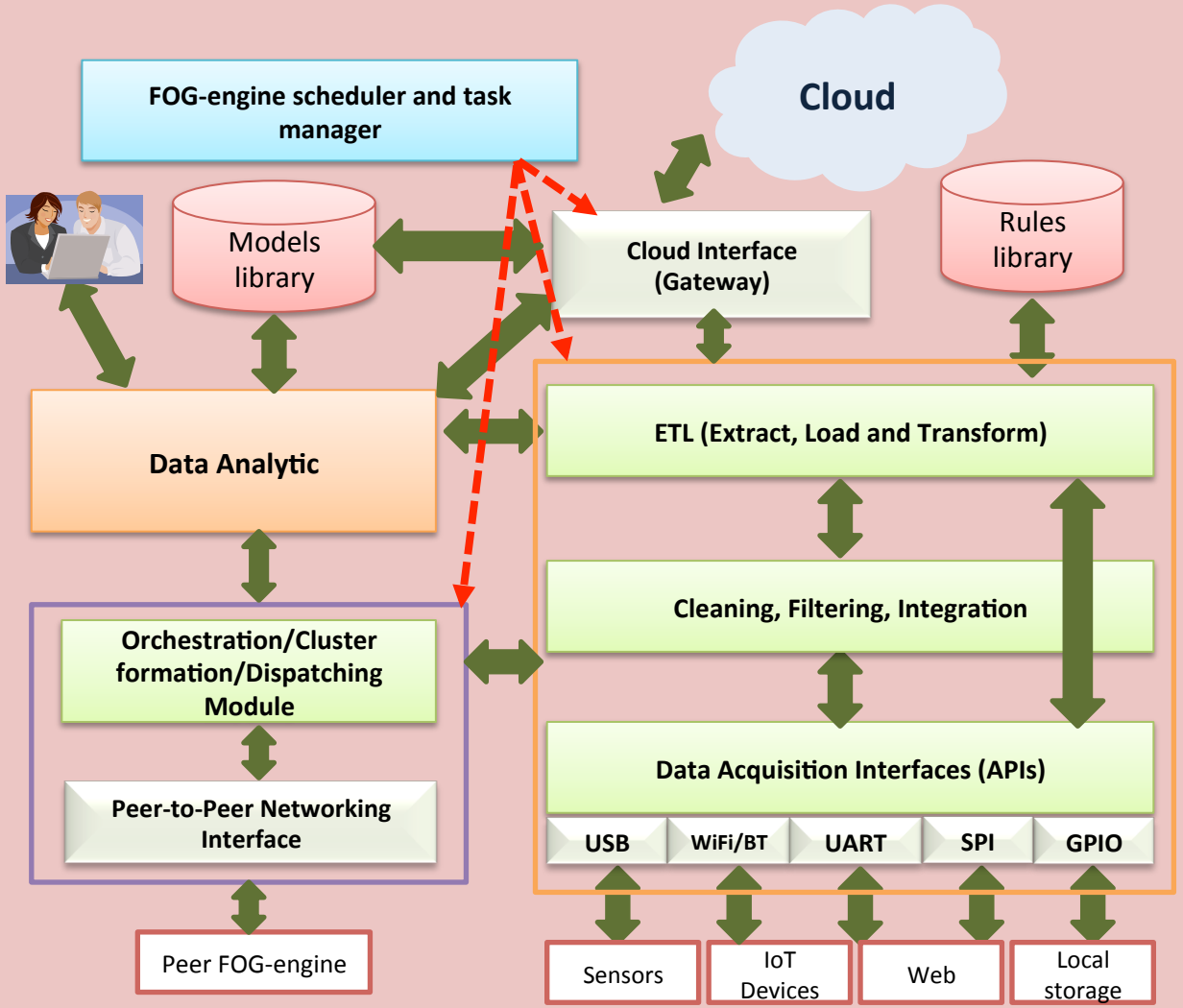
A Modified Data Analytics Flow



General Architecture of FOG-Engine



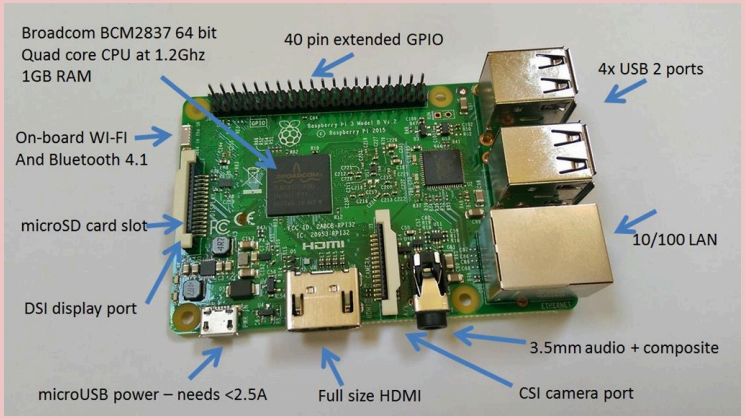
Detailed Architecture of FOG-Engine

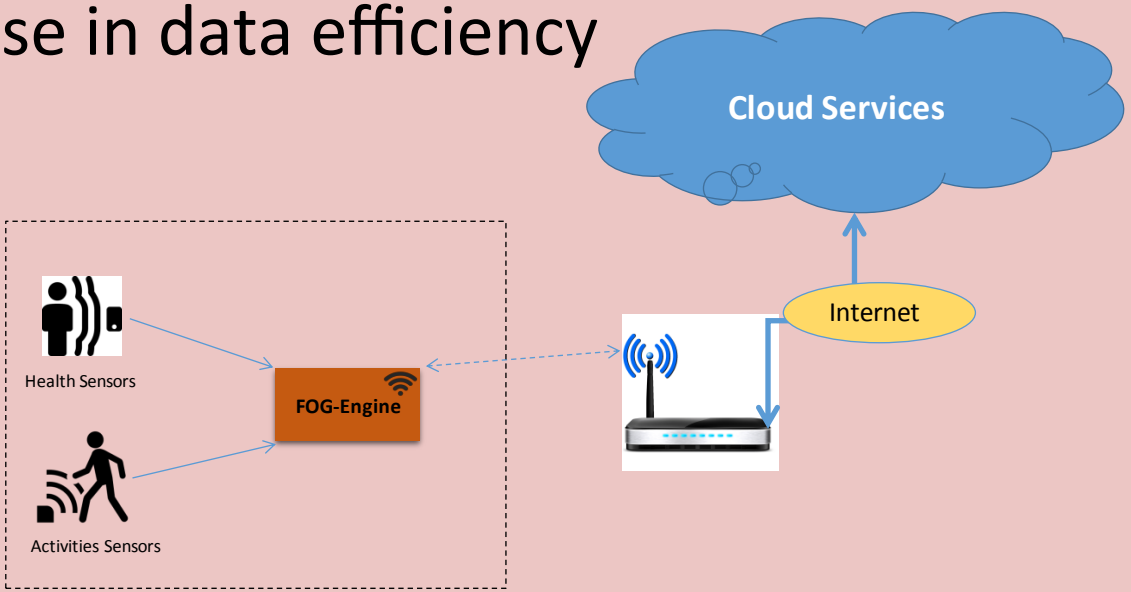


USB: Universal serial bus
BT: Bluetooth
UART: Universal Asynchronous Receiver/Transmitter
SPI: Serial Peripheral Interface Bus
GPIO: General-purpose input/output pins

FOG-Engine Prototyping

- Raspberry Pi 3.0
- Python Library
- Results
  - 40% reduced in data size
  - 60% increase in data efficiency





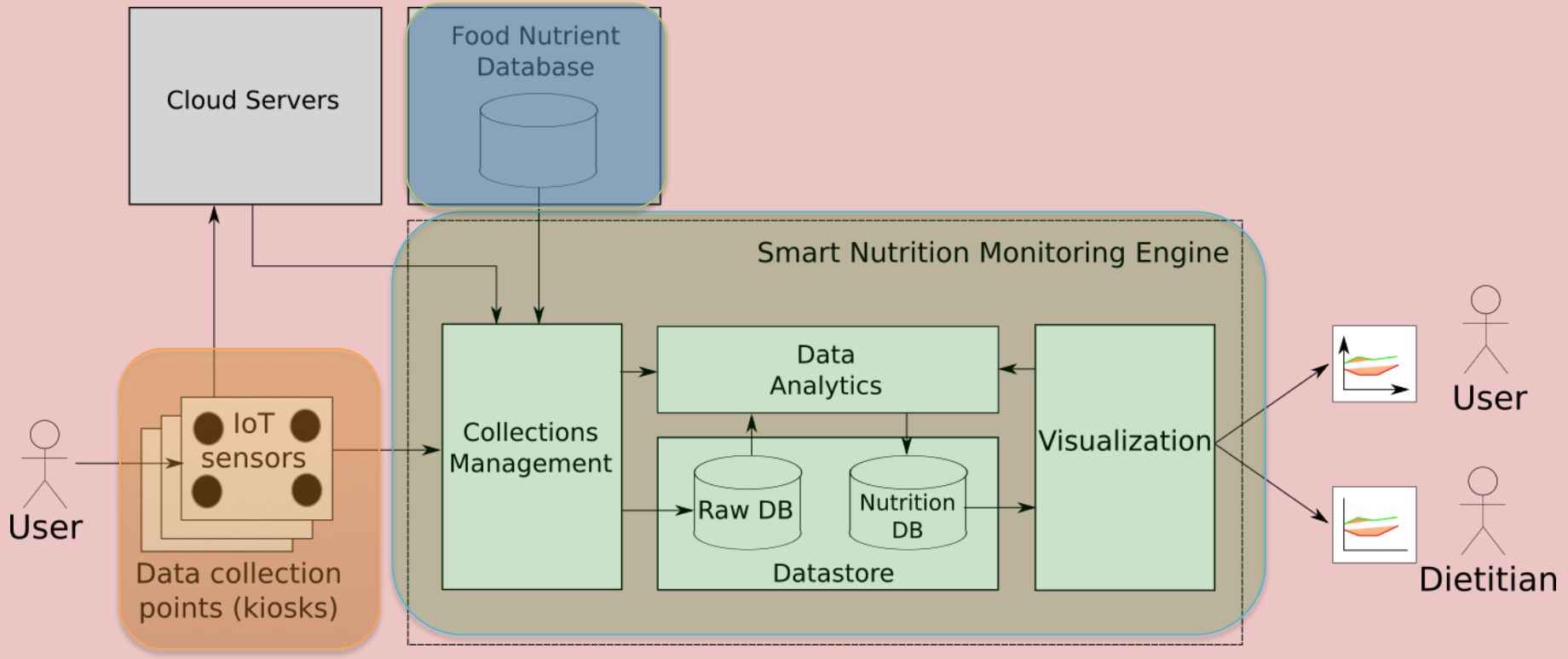
Smart Nutrition Monitoring System using Fog Computing

- Overweight and obesity in Adults
  - US: 70%
    - $200B
  - Australia: 63%
    - $14B
  - India: ~20%
    - 3rd most obese country in the world

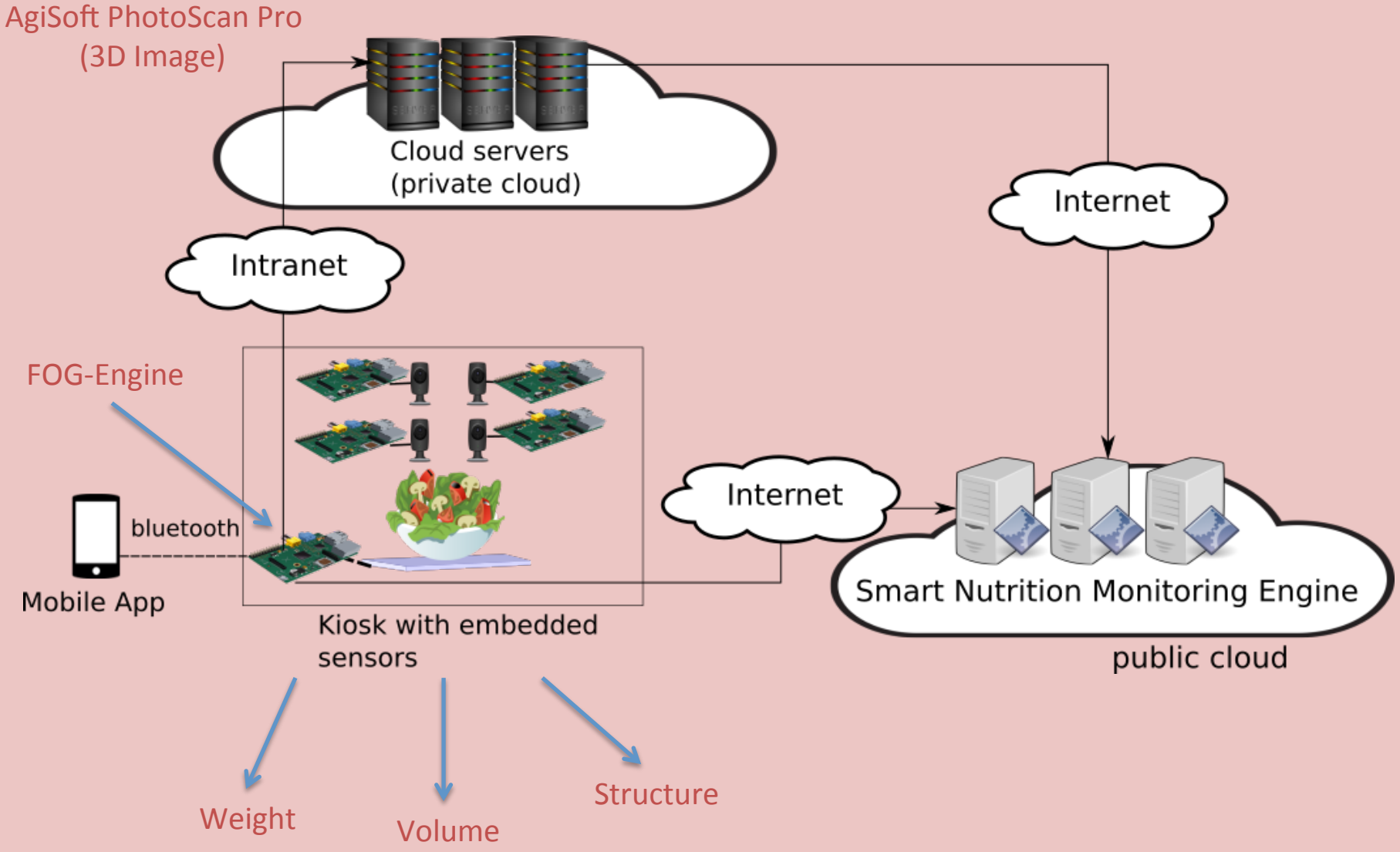
Smart Nutrition Monitoring System

- Project Scope
  - Take away food (50M meals out each week in Australia)
- Non-invasive
  - Minimizing the amount of direct input and actions from users
- High data accuracy and reliability
  - Heterogeneous IoT sensors
- Scalability
  - Cloud and Fog Computing

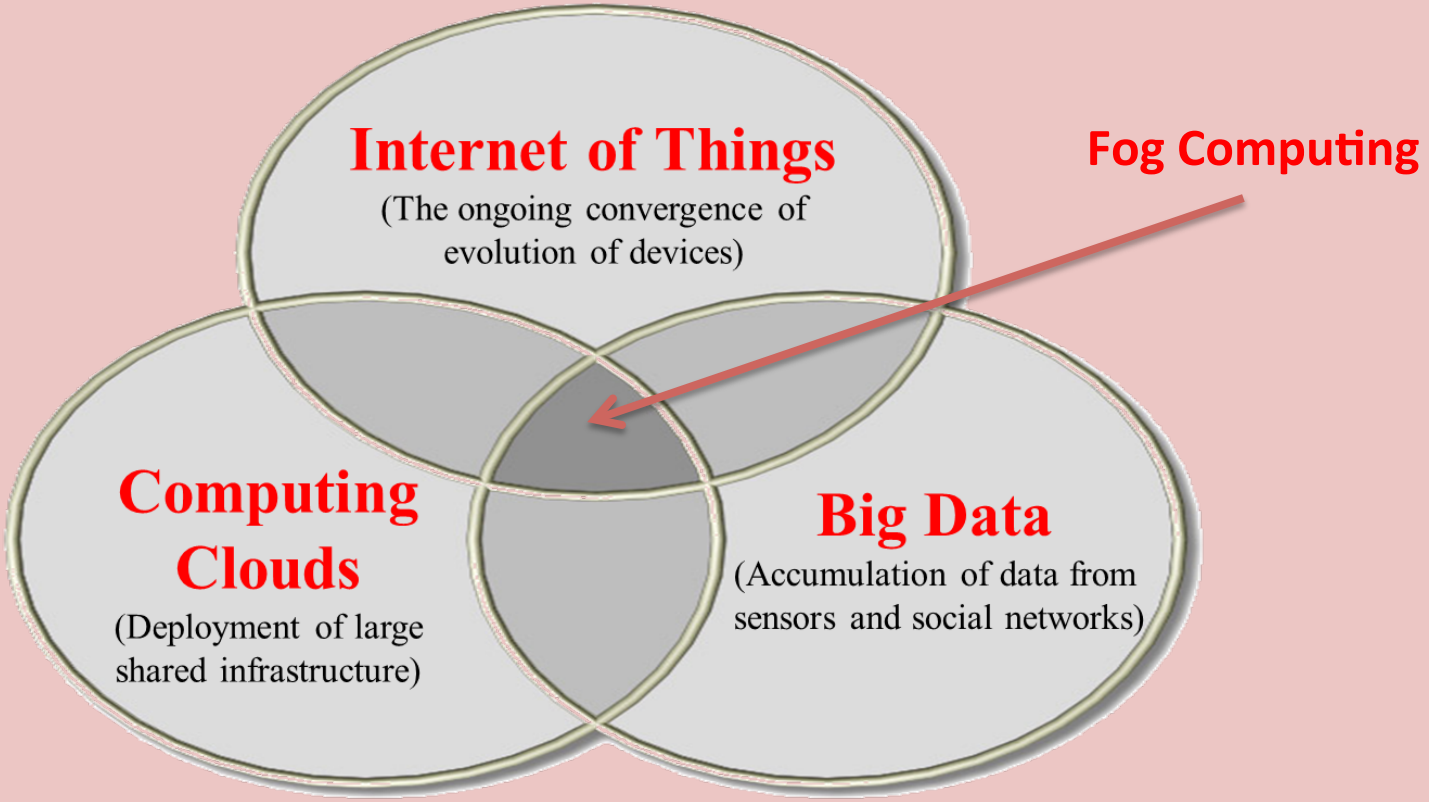
Architecture of Smart Nutrition Monitoring System



System Prototype



Open Issues and Challenges



- Innovative Machine Learning
- Decentralized Resource Scheduling
- Reliability and Power Efficiency
- Information and Security Management

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Thank You

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