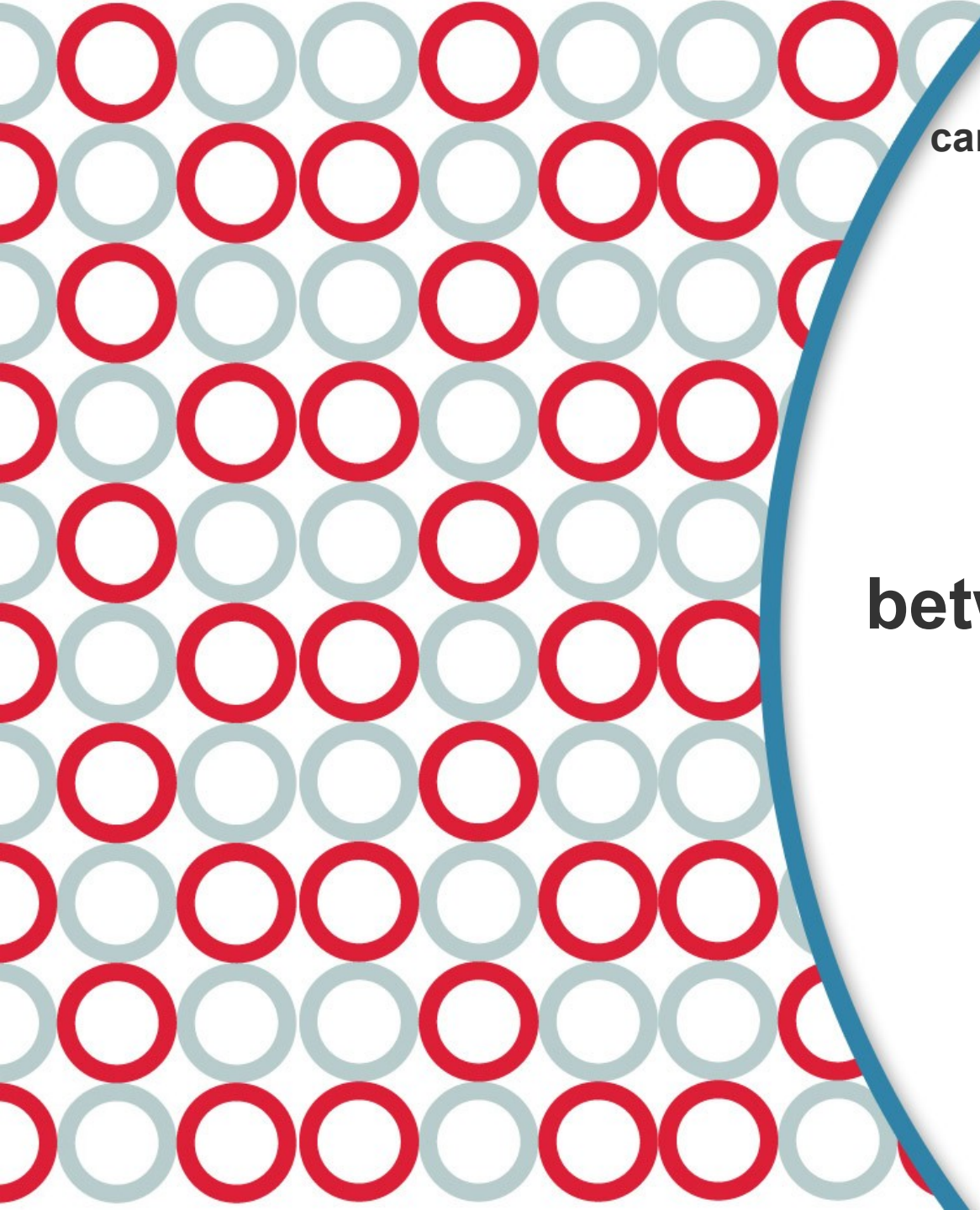

Разпределено машинно самообучение с приложения в роботиката и IoT - 2020/2021

Fog Computing: between IoT Devices and The Cloud

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About Us

Trayan Iliev

– CEO of IPT – Intellectual Products & Technologies

– Oracle® certified programmer 15+ Y

– End-to-end reactive fullstack apps with Java, ES6/7, TypeScript, Angular, React and Vue.js

– 12+ years IT trainer

– Voxxed Days, jPrime, jProfessionals, BGOUG, BGJUG, DEV.BG speaker

– Lecturer @ Sofia University – courses: Internet of Things (with SAP), Multiagent Systems and Social Robotics

Since 2003: IT Education Evolved

- Spring 5, Webflux, Java SE/Web/EE 7/8/9
- Reactive Robotics & IoT with Reactor / RxJava / Akka
- Node.js + Express + React + Redux + GraphQL
- Angular + TypeScript + Redux (ngrx)
- SOA & REST HATEOAS
- DDD, Real Time Eventing & Reactive Microservices

Fog Computing – between IoT Devices and The Cloud

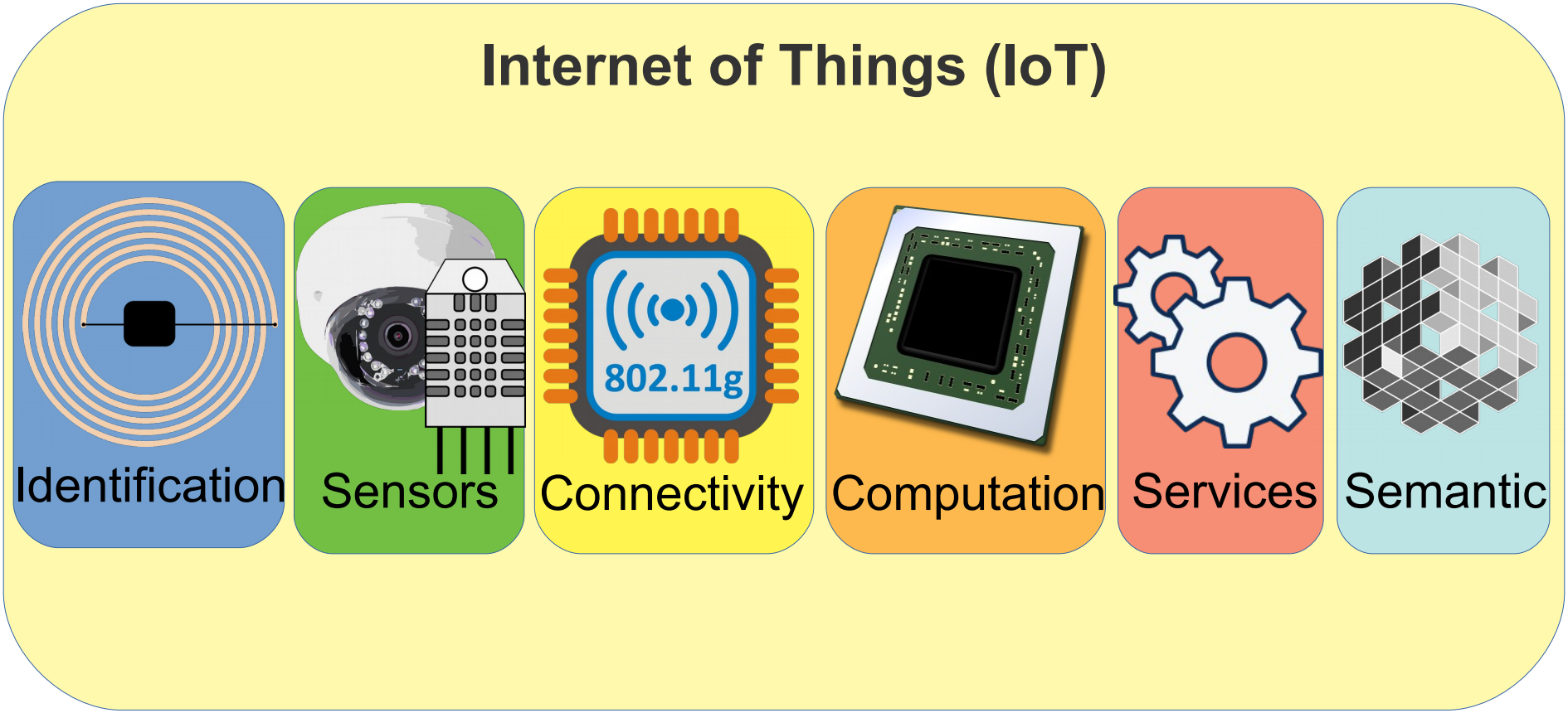
- Edge, Fog, Mist & Cloud Computing
- Fog domains and fog federation, wireless sensor networks, multi-layer IoT architecture
- Fog computing standards and specifications
- Practical use-case scenarios & advantages of fog
- Fog analytics and intelligence on the edge
- Technologies for distributed asynchronous event processing and analytics in real time
- Lambda architecture – Spark, Storm, Kafka, Apex, Beam, Spring Reactor & WebFlux
- Eclipse IoT platform

IoT, IoE, WoT – What It Means?

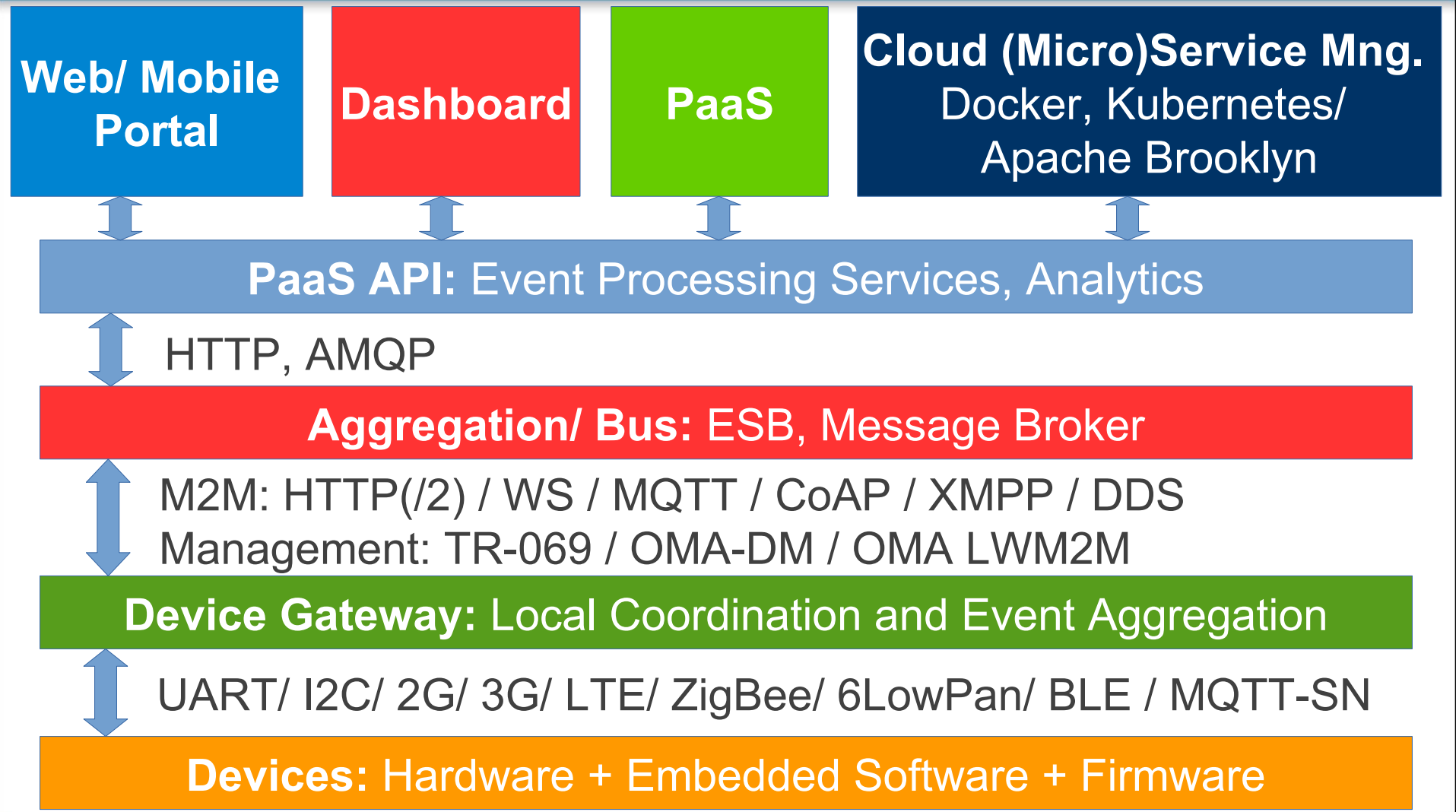
The **Internet-of-Things (IoT)** is a self-configuring and adaptive network which connects real-world things to the Internet enabling them to communicate with other connected objects leading to the realization of a new range of ubiquitous services.

R. Minerva et al. - Towards a definition of IoT
Technical report, IEEE, 2015

Key Elements of IoT



IoT Services Architecture



Cloud Computing - Definition

Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model is composed of five essential characteristics, three service models, and four deployment models.

National Institute of Standards and Technology

Essential Characterisics of Cloud

- On-demand self-service
- Broad network access
- Resource pooling
- Rapid elasticity
- Measured service

Cloud Service Models

- Software as a Service (SaaS)
- Platform as a Service (PaaS)
- Infrastructure as a Service (IaaS)

Cloud Deployment Models

- Private cloud
- Community cloud
- Public cloud
- Hybrid cloud

Edge Computing (Mesh Computing)

"… places applications, data and processing at the logical extremes of a network rather than centralizing them. Placing data and data-intensive applications at the Edge reduces the volume and distance that data must be moved."

IoT Guide
http://internetofthingsguide.com/d/edge_computing.htm

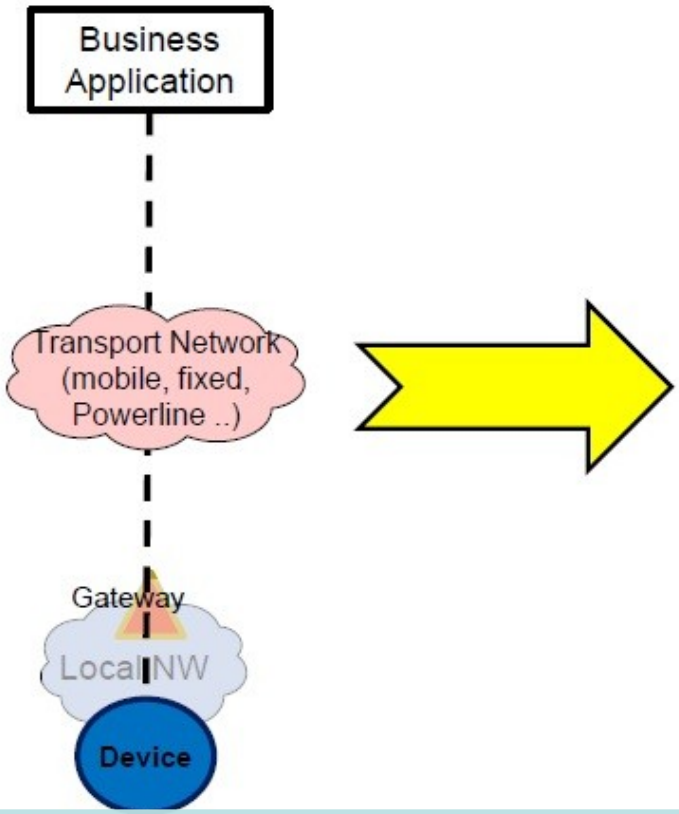
Fog Computing: Definition

A horizontal, system-level architecture that distributes computing, storage, control and networking functions closer to he users along a cloud-to-thing continuum.

OpenFog™ Consortium

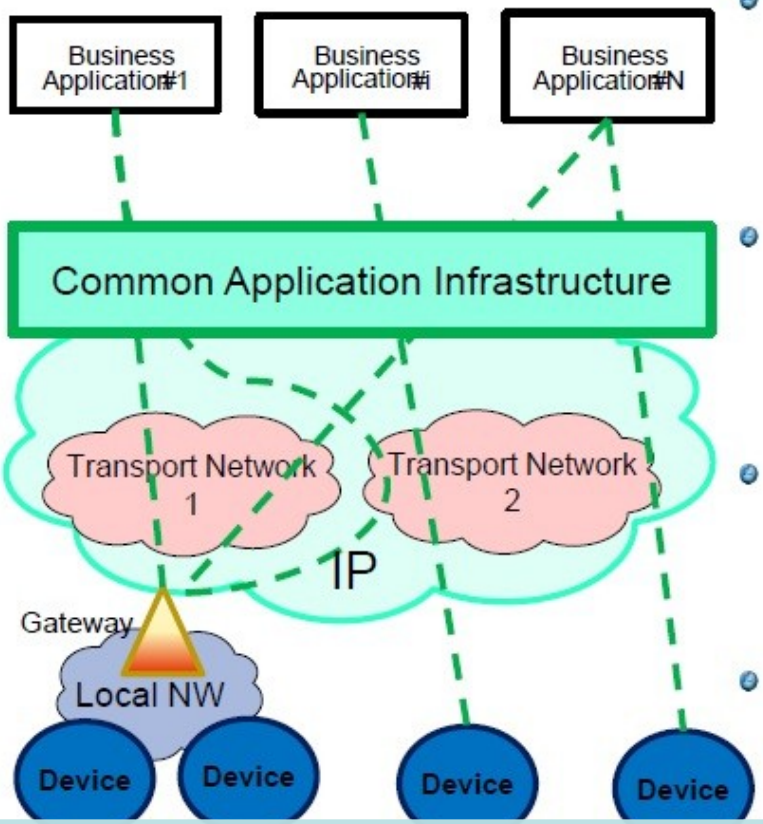
Vertical vs. Horizontal IoT

Pipe (vertical):
1 Application, 1 NW,
1 (or few) type of Device



Horizontal (based on common Layer)

Applications share common infrastructure, environments and network elements



- *M2M Applications providers* run individual M2M services. Customer is Device owner
- *M2M Service provider* hosts several M2M Applications on his Platform.
- *Wide Area Transport Network operator(s)* Customer is the M2M service provider
- *End user* owns / operates the Device or Gateway

http://www.iot-week.eu/overview_2013/iot-week-2012/programme-1/tuesday-1/presentations/semantic-interoperability/K1_ETSI-M2M-oneM2M-and-the-need-for-semantics-IoTWeek2012.pdf, By Joerg Swetina (NEC)- ETSI M2M / oneM2M and the need for semantics

Fog vs. Edge Computing - Diff

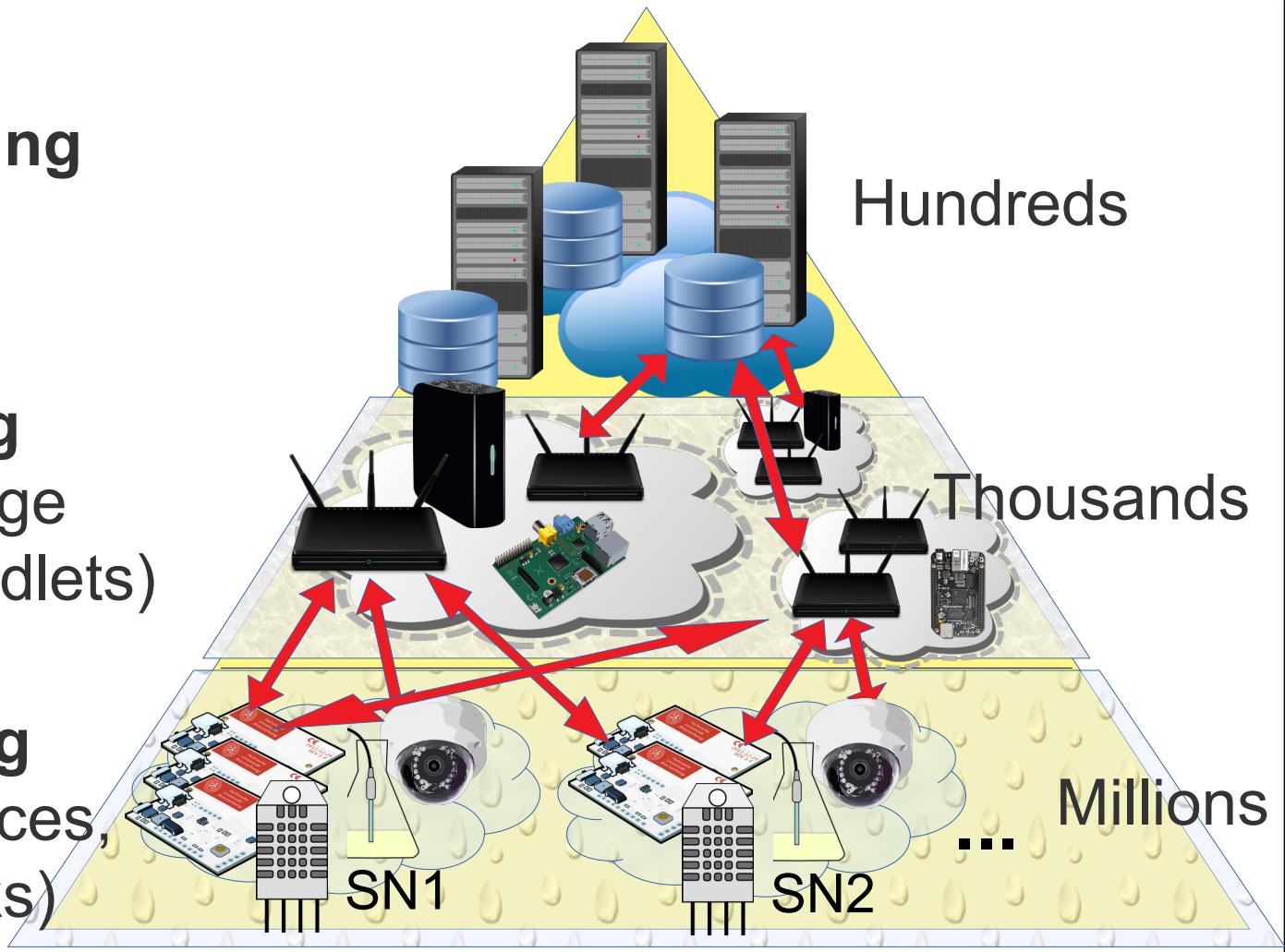
Fog computing	Edge computing
Works with the Cloud	Defined separately without Cloud
Multi-layered architecture, N-tier deployments, multiple IoT verticals	Limited number of local layers, not aware of IoT verticals
Independent of the devices and aware of the entire fog domain	Device and few local services aware, no domain awareness
Addresses networking, storage, control, processing acceleration	Addresses computation only, little interoperability
Analytics: collection, analysis, ML, anomalies, optim., multiple devices	Analytics scoped to a single device – printer, camera, machine, etc.
End-to-end (E2E) security – data protection, session, hardware level	Custom security, partial point solution, VPN, Firewall
Virtualization, containerization, App/ Soft PLC hosting, RT control, modularity, High Availability (HA)	No virtualization, Hard PLC/ Soft PLC stack integrated on device hardware, not modular, not HA

Cloud, Fog and Mist Computing

Cloud Computing
(Data-centers)

Fog Computing
(Fog Nodes, Edge Gateways, Cloudlets)

Mist Computing
(Smart IoT Devices, Sensor Networks)



Mist Computing - Definition

Mist computing is a lightweight and rudimentary form of computing power that resides directly within the network fabric at the edge of the network, the fog layer closest to the smart end-devices, using microcomputers and microcontrollers to feed into fog computing nodes and potentially onward towards the cloud computing services.

National Institute of Standards and Technology

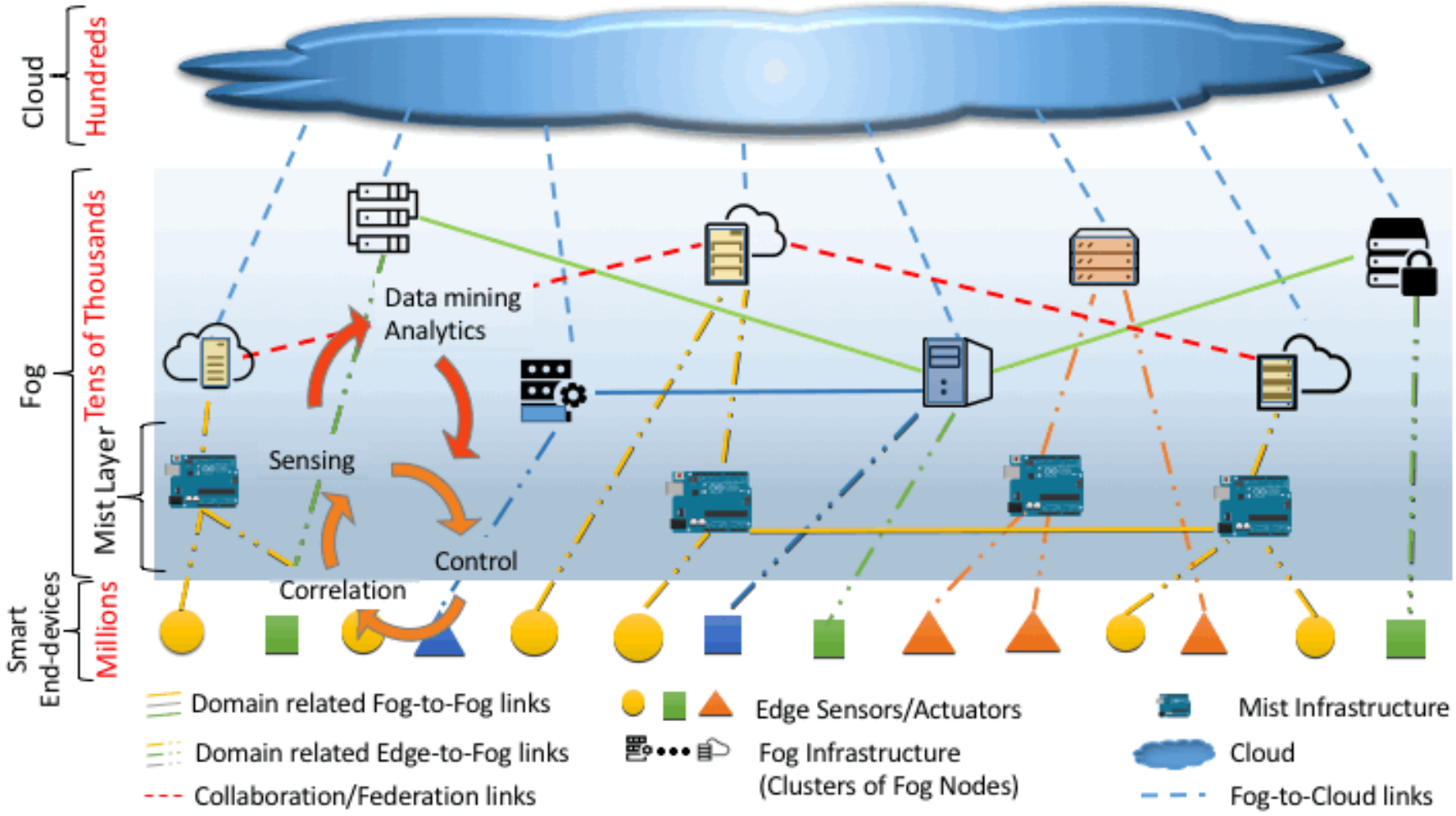
Why Fogging?

- Exponential Data in Realtime – data generated by IoT devices is growing exponentially – especially high bandwidth devices and apps like: LIDARs, 3D cameras, US arrays, gaming, streaming, augmented reality, etc.
- If all data should go to the cloud for analysis and speech/ image/ 3D scene recognition → a recipe for network congestion, high-latency, and self-made DoS.
- Many metrics like performance, efficiency, scalability, latency, security, bandwidth, reliability, privacy could be greatly improved if the processing, analysis, and partially decision making are done locally – close to the source of data.

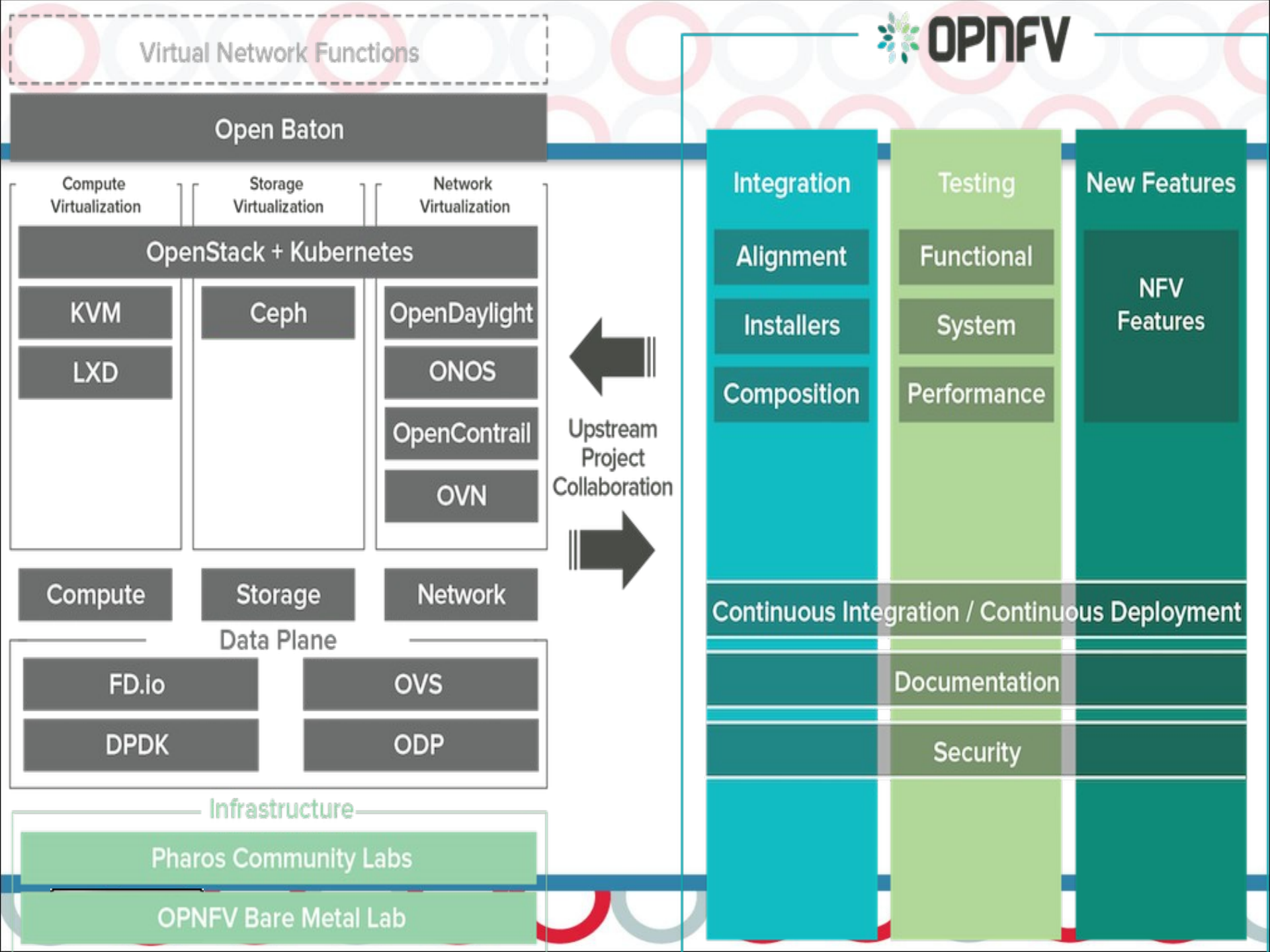
Fog Nodes, Domains & Federation

- Fog Node – The physical and logical network element that implements fog computing services. It is somewhat analogous to a server in cloud computing.
- Fog Domain – seamlessly extends cloud computing to the edge for secure control and management of domain specific hardware, software, and standard compute, storage and network functions.
- Fog Federation – secure control and management of ***multiple fog domain instances***, including edge devices, computes, networking, storage & services in a distributed and consistent manner, providing horizontal expansion of functionality over disperse geolocations.

Fog Comuting – a Cloud-Based Ecosystem for Smart End-Devices



https://csrc.nist.gov/csrc/media/publications/sp/800-191/draft/documents/sp800-191-draft.pdf, National Institute of Standards and Technology (NIST) Definition of Fog Computing – Special Publication Draft 800-191


Virtual Network Functions
Open Baton
Compute Virtualization
Storage Virtualization
Network Virtualization
OpenStack + Kubernetes
KVM
LXD
Ceph
OpenDaylight
ONOS
OpenContrail
OVN
Upstream Project Collaboration
Compute
Storage
Network
Data Plane
FD.io
DPDK
OVS
ODP
Infrastructure
Pharos Community Labs
OPNFV Bare Metal Lab
OPNFV
Integration
Alignment
Installers
Composition
Testing
Functional
System
Performance
New Features
NFV Features
Continuous Integration / Continuous Deployment
Documentation
Security

IoT Networking & Identification

- Time-Sensitive Networking (TSN) – IEEE 802.1
- ISO/IEC 20248 Automatic Identification and Data Capture Techniques – QR Code, RFID, NFC – secure identification of Things.
- GS1's EPC Tag Data Standard (TDS) and EPCglobal Architecture Framework (EPC Network) – allows storing and querying of data related to objects identified with Electronic Product Code numbers.
- IPv6 – allows identification of network interaces and IP package routing, not permanent

Fog Standards and Specifications

- National Institute of Standards and Technology (NIST) *Definition of Fog Computing* – Special Publication Draft 800-191
- OpenFog Consortium – *OpenFog Reference Architecture for Fog Computing* – medium to high level description of system architectures for fog nodes and networks, including of multiple viewpoints (Functional, Deployment), views (Software, System, Node), and Perspectives (cross-cutting concerns). Based on:
- ISO/IEC/IEEE 42010:2011 – *Systems and software engineering — Architecture description*

NIST Definition of Fog Computing

Fog computing is a horizontal, physical or virtual resource paradigm that resides between smart end-devices and traditional cloud or data centers. This paradigm supports vertically-isolated, latency-sensitive applications by providing ubiquitous, scalable, layered, federated, and distributed computing, storage, and network connectivity.

National Institute of Standards and Technology

Fog Computing Characteristics - I

- Contextual location awareness, and low latency
- Geographical distribution & distributed deployment
- Large-scale sensor networks – environment monitoring, Smart Grid → distributed computing and storage
- Very large number of nodes – geo-distributed
- Support for mobility – mobile devices: smartphones, etc.
- Real-time interactions – streaming, lambda architecture
- Predominance of wireless IoT access: analytics, compute
- Heterogeneity – deployed in wide variety of environments

Fog Computing Characteristics - II

- Interoperability and federation - seamless support of certain services (e.g. real-time streaming) requires the cooperation of different providers.
- Support for real-time analytics and interplay with the Cloud -while Fog nodes provide localization, therefore enabling low latency and context awareness, the Cloud provides global centralization. Many applications require both Fog localization and Cloud globalization, particularly for analytics and Big Data.
- Fog is particularly well suited to real-time streaming analytics as opposed to historical, Big Data batch analytics that is normally carried out in a data center.

Fog as a Service (FaaS)

- Pay-as-you-go model
- Includes:
  - Software as a Service (SaaS)
  - Platform as a Service (PaaS)
  - Infrastructure as a Service (IaaS)

OpenFog Consortium

- Founded in November 2015 by ARM, Cisco, Dell, Intel, Microsoft and Princeton University
- Open participation from across industry, academia and non-profit organizations that have an interest in the emerging IoT landscape
- Defines open architectural framework enabling IoT industry convergence and game-changing innovation through fog computing
- Efforts complementary to other initiatives like: Industrial Internet Consortium (IIC), ETSI-MEC (Mobile Edge Computing), OPC-UA, Open Connectivity Foundation (OCF), OpenNFV, etc.

Example Use Cases

- Traffic Control and Smart Cars – Vehicle-to-X – including: Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), Vehicle-to-Manufacturer (V2M), multiple public and private fog and cloud networks.
- Security Cameras and Surveillance – in smart cities / homes, retail stores, factories, public transportation, airports – terabytes per day by single camera → local processing, anomaly detection, and decision making.
- Smart cities- parking, shopping, healthcare, infrastructure
- Smart Buildings – HVAC, lighting, doors, parking, security, elevtors, support for smartphones, tablets, etc.

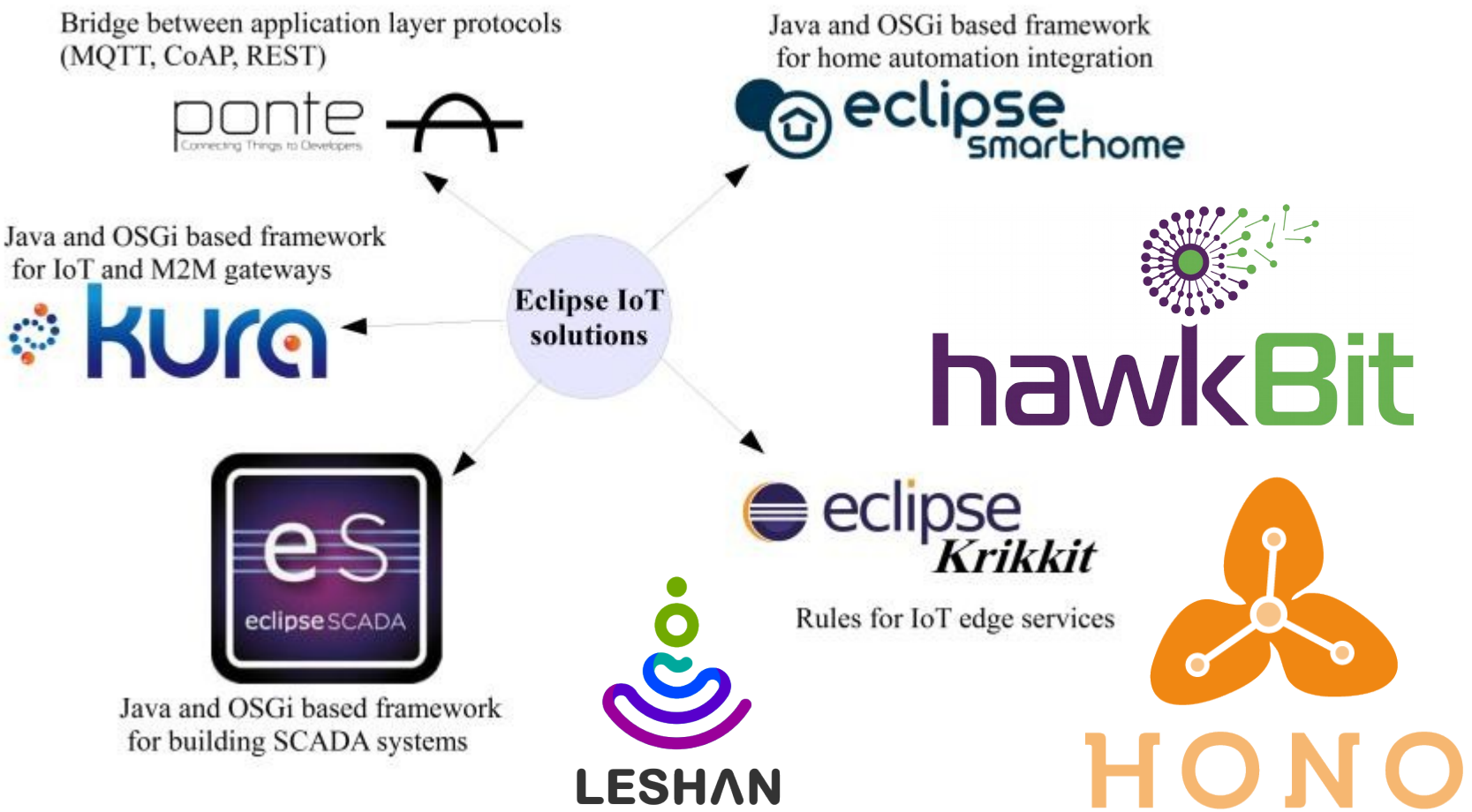
Core Principles

- Scalable
- Agile and open
- Secure
- Autonomous
- Flexible & programmable
- Highly available
- Reliable
- Remotely serviceable
- Hierarchically structured based on business needs

Fog Analytics

- Descriptive Analytics
- Reactive (Diagnostic) Analytics
- Predictive Analytics
- Prescriptive Analytics

Eclipse IoT Platform



Based on: https://www.researchgate.net/publication/279177017_Internet_of_Things_A_Survey_on_Enabling_Technologies_Protocols_and_Applications, By Ala Al-Fuqaha et al. - Internet of Things: A Survey on Enabling Technologies, Protocols and Applications

Thank's for Your Attention!

Trayan Iliev

CEO of IPT – Intellectual Products & Technologies

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