



# OpenFog Reference Architecture

Presented by Dr. Maria Gorlatova

OpenFog Consortium Communications Working Group Co-chair,  
Technical Committee Member



# My background



- Associate Research Scholar at Princeton University
- Ph.D. from Columbia University



- Research in fog computing
  - Enabling interactivity and cognition in IoT systems
  - Communication protocols for fog computing (as part of a DARPA program jointly with BAE Systems, LGS, MIT, and NYU)
- Co-chair of the OpenFog Consortium Communications Working Group
  - Member of the technical committee
  - TPC member of the 2017 Fog World Congress



# OpenFog Consortium







## A Growing, Global Ecosystem

**Affiliations**





**Founders**

**Contributing Members**
















































55 members strong, headquartered in 14 countries as of February 2017

# OpenFog Consortium goals

## *Technology*

- Develop** an open architecture framework for fog computing
- Solve** tough challenges in distributed systems, security, communications, networking
- Identify**, build and share fog computing use cases and requirements
- Create** testbeds to promote and demonstrate interoperability and composability of solutions

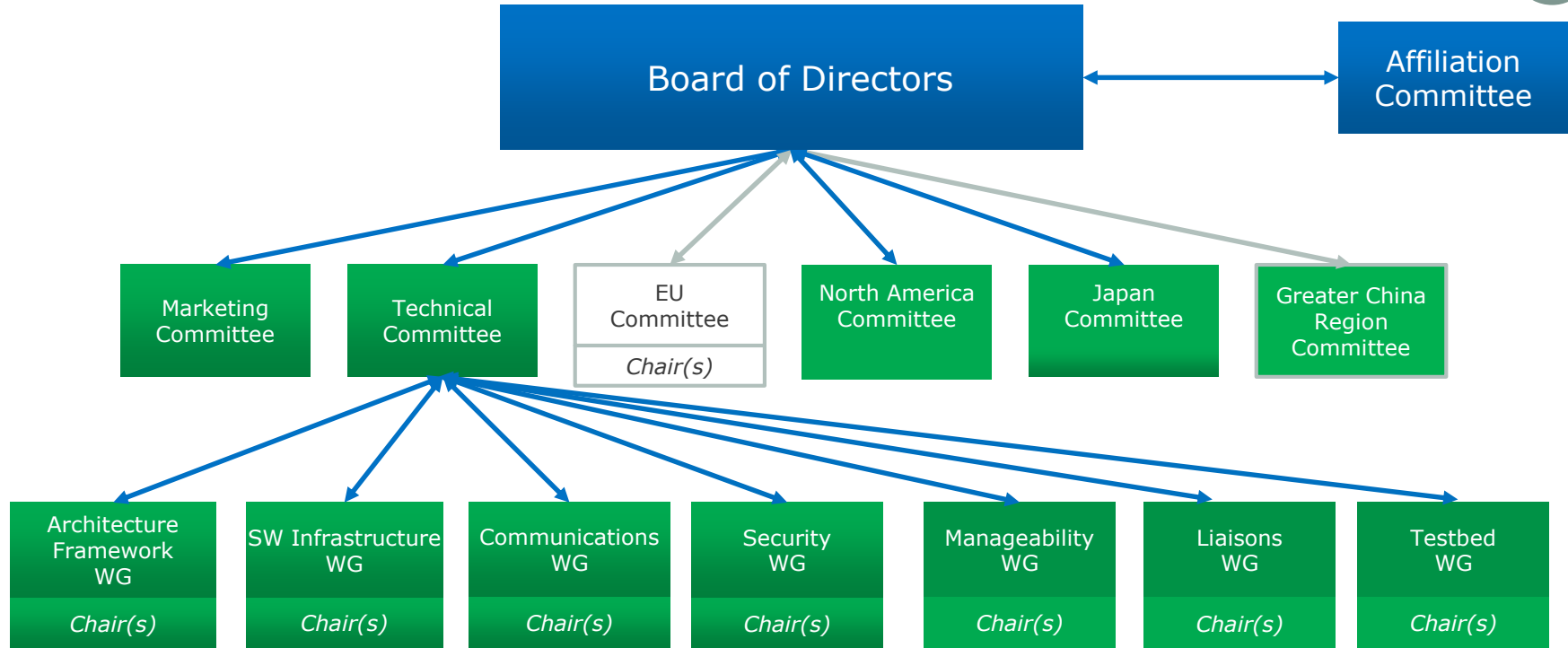
## *Industry-wide Collaboration*

- Foster** university and industry partnerships to tackle challenging technical problems, leverage research and educate future workers
- Initiate** and support operational models and testbeds that showcase innovation
- Provide** a forum to share ideas and facilitate business development opportunities
- Influence** standards development through strategic affiliations

## *Education*

- Gain** exposure to advanced research concepts from university & industry members
- Promote** innovation through global industry events and plugfests
- Evangelize** value, share best practices, showcase real-world applications
- Educate** through e-learning, publications and conferences

# OpenFog Consortium organizational structure



# What is fog computing?

## System-Level

from things to the edge, and over the core to the cloud, spanning multiple protocol layers

(works over and inside wireless and wireline networks)

## Architecture

for distributing, orchestrating, managing, securing resources and services

(not just placing servers, computing resources, apps, or small clouds at the edges)

CLOUD

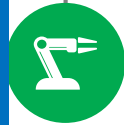
FOG COMPUTING

A system-level horizontal architecture that distributes computing, storage, and networking closer to users, and anywhere along the cloud-to-thing continuum

## Horizontal

Supports multiple industries

(not limited to any specific industry, network type, or application domain)

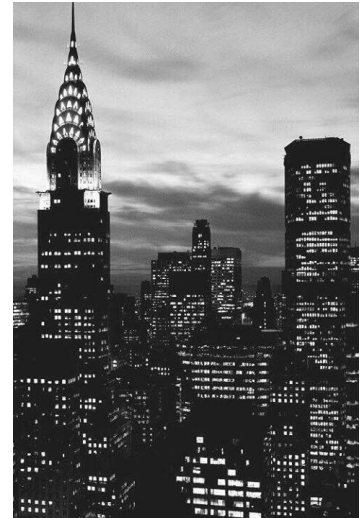
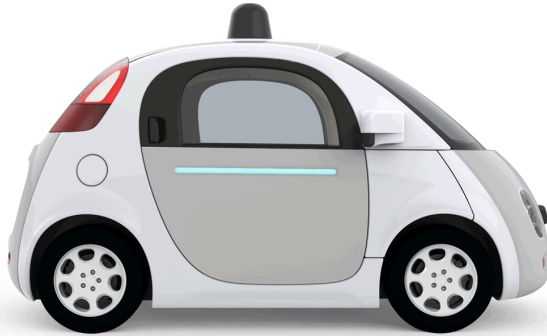


## Cloud-to-Thing Continuum

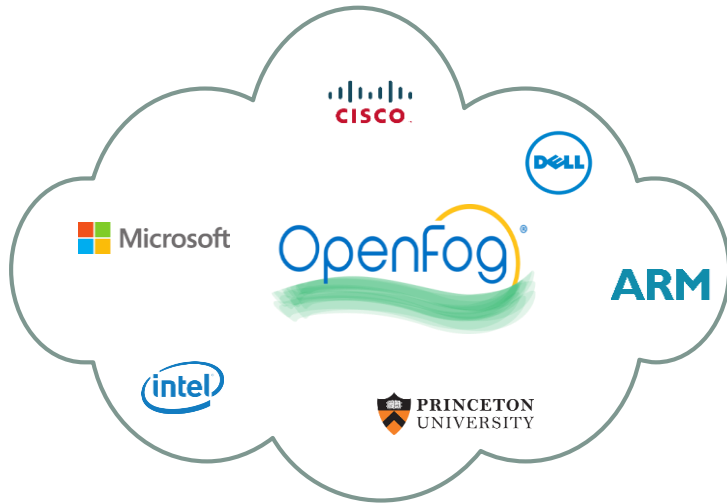
Distributes resources and services to anywhere along the continuum

(not just at the edges)  
Converged cloud/fog platforms and services  
(not just isolated edge computing devices / apps)

# Fog enables advanced IoT, 5G & AI use cases



# Building the necessary interoperability of fog-enabled applications requires a collaborative approach



Proprietary or single vendor solutions slows down adoption and innovation

An open architecture will:

- Provide a robust new platform for product development
- Increased quality and innovation through competition in the open environment
- Lead to a vibrant, growing supplier ecosystem
- Accelerate market adoption
- Lower system costs



# Unified framework approach parallels Internet approach

## TCP/IP

A unified framework to  
distribute packets

## Reference architecture

A unified framework to  
distribute resources and services  
and to  
manage, orchestrate, and secure  
them

Changing the way the world works via unified frameworks

# OpenFog Reference Architecture

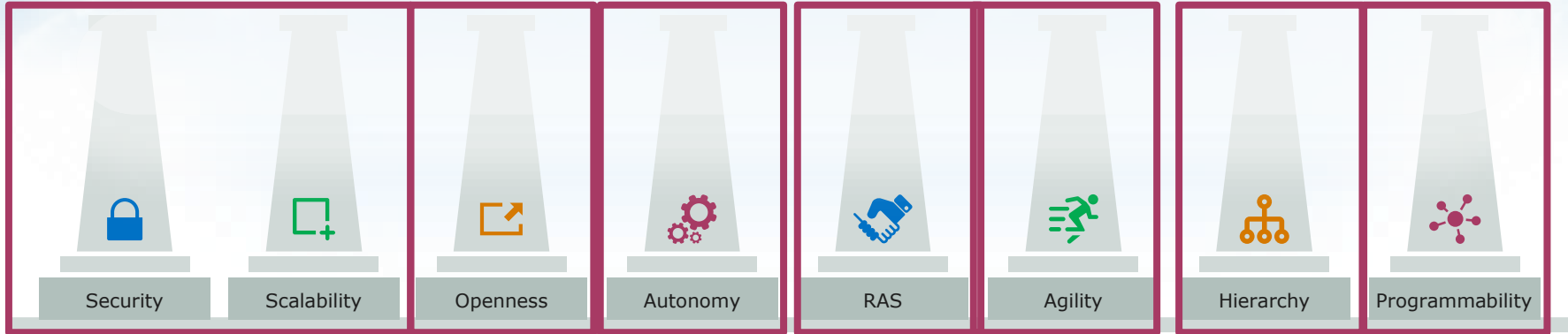
[www.OpenFogConsortium.org/RA](http://www.OpenFogConsortium.org/RA)

# OpenFog reference architecture: core principles



Requirements to every part of supply chain:

- Component manufacturers
- System vendors
- Software providers
- Application developers



- Specific to deployment needs
- Trust
- Attestation
- Privacy

- Localized command, control & processing
- Orchestration & analytics
- Avoidance of network taxes

- Resource visibility & control
- White box decision making
- Interop & data normalization

- Flexible
- Cognition & agility
- Value of data

- Reliability
- Availability
- Serviceability

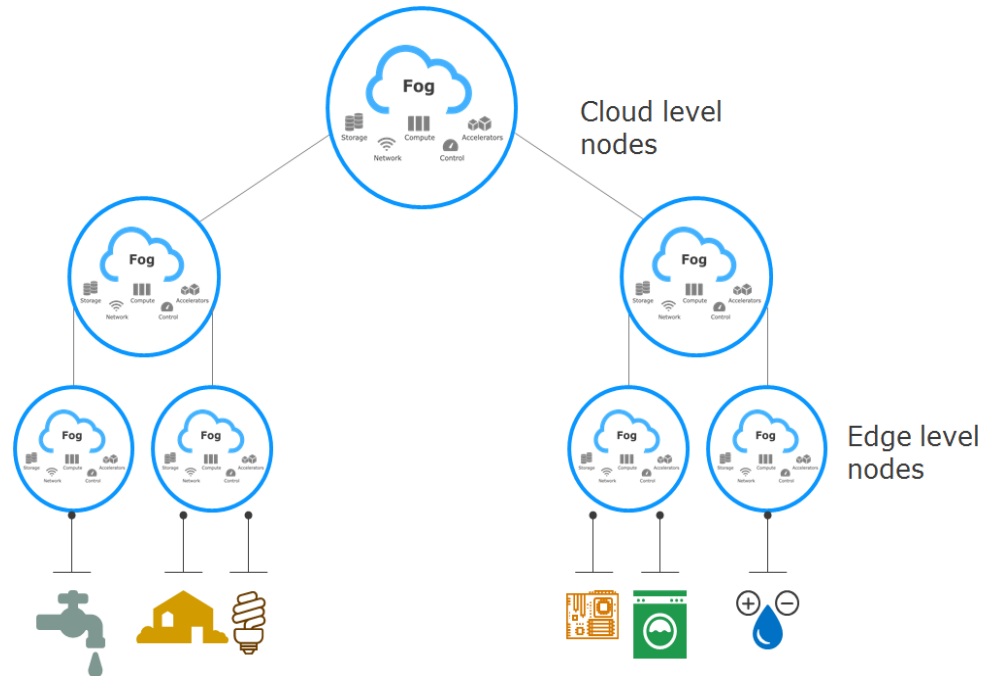
- Tactical & strategic decision making
- Data to wisdom

- Fully cloud enabled
- Computational & System
- Autonomy at all levels

- Programmable SW/HW
- Virtualization & multi-tenant
- App fluidity

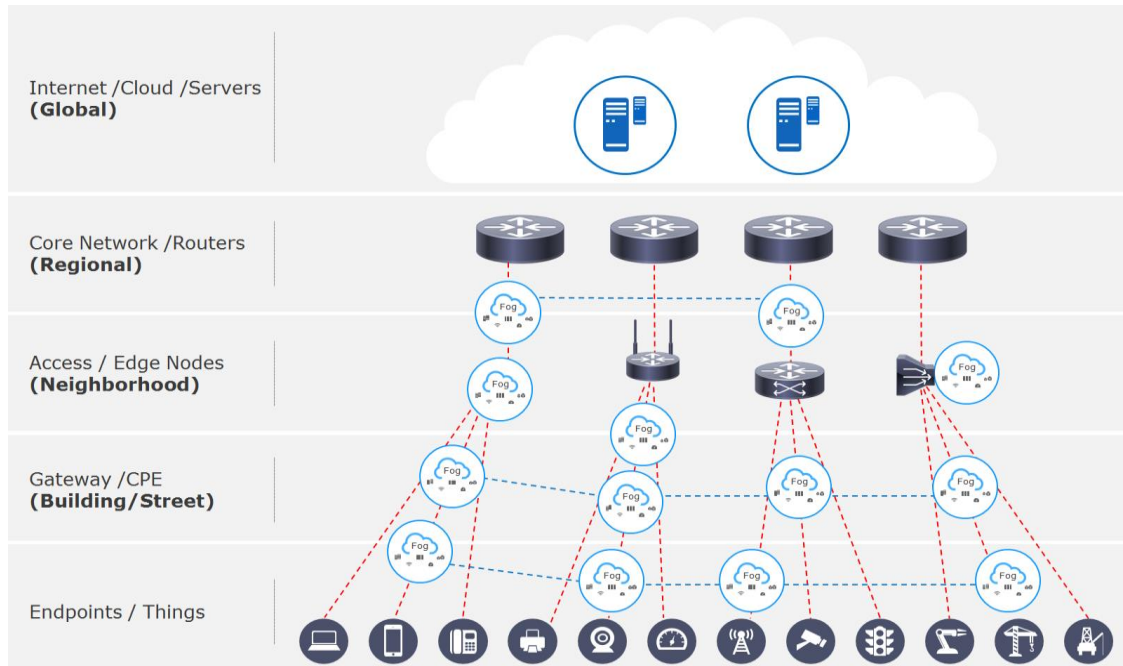
# Multi-tier deployments

- Hierarchy, reliability, programmability
  - Applications can span multiple nodes
  - Number of tiers determined by a use case



# Smart city deployment example

- Nodes communicate up and down and laterally
- Nodes form a mesh, aiding with
  - Load balancing
  - Resilience
  - Fault tolerance
- Computing logic, decision-making at multiple points in the hierarchy



*Smart city fog deployment: buildings, neighborhoods, regions connected with each other*

# Multi-layer architecture addressing cross-cutting concerns

Applications

Supporting software

Platform

Fog nodes



Performance & Scale  
(RT, QoS, etc.)



Security  
(ID, HW-RoT, Attestation, Authentication, Authorization,...)



Manageability  
(RAS, Alerting, Orchestration, Operations, Discovery,...)



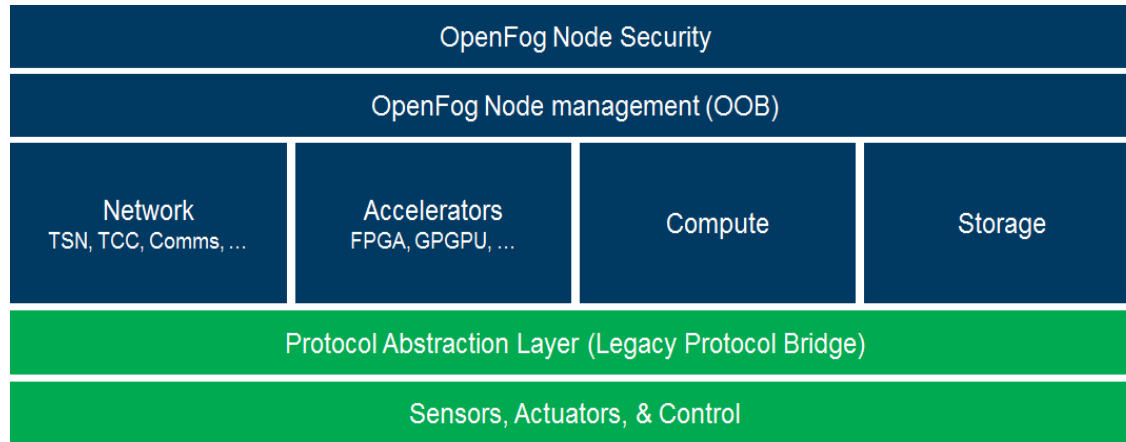
Data, Analytics & Control  
Machine Learning, Rules Engines, Cognition, etc.



IT Business & Cross Fog Applications

# Lowest level of architecture description: node view

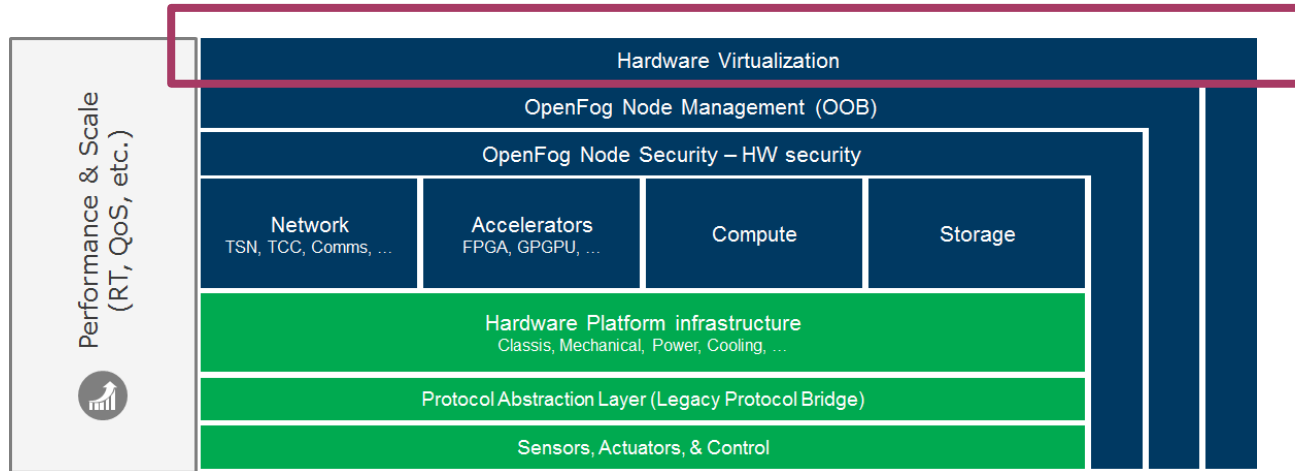
- Targeted at chip designers, silicon manufacturers
- Architecture ideas, design considerations from IoT/sensor, mobile, server computing nodes



*Fog node architecture*

# System architecture view

- Targeted at system architects, electronics manufacturers
- Creating a fog platform, small (resembling a WiFi router) or large (resembling a server blade)
- Concerns: physical form factor, serviceability, modularity



*Fog system architecture*

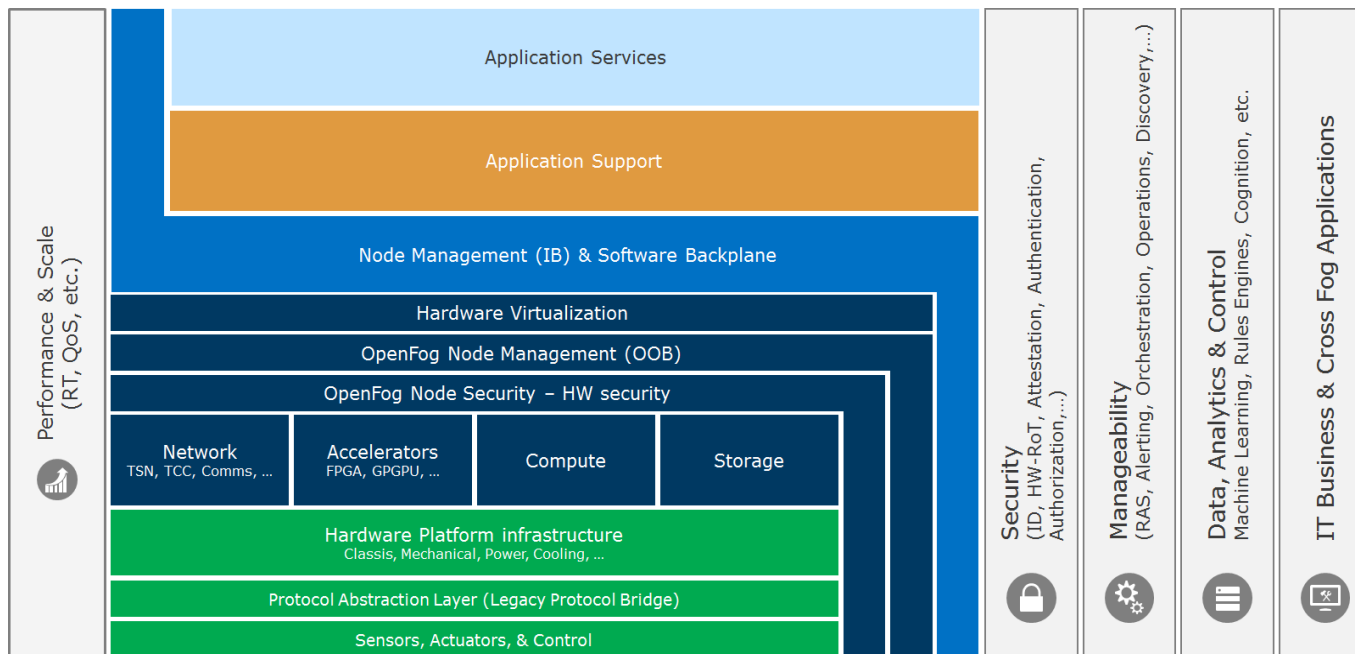


# Software architecture view

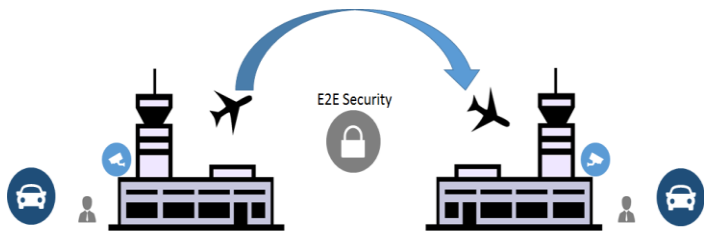
- Targeted at software architects, solution designers
- Software backplane: drivers, OS, communication and security services
  - Under active development
- Fog-specific application services: core, analytics, integration services



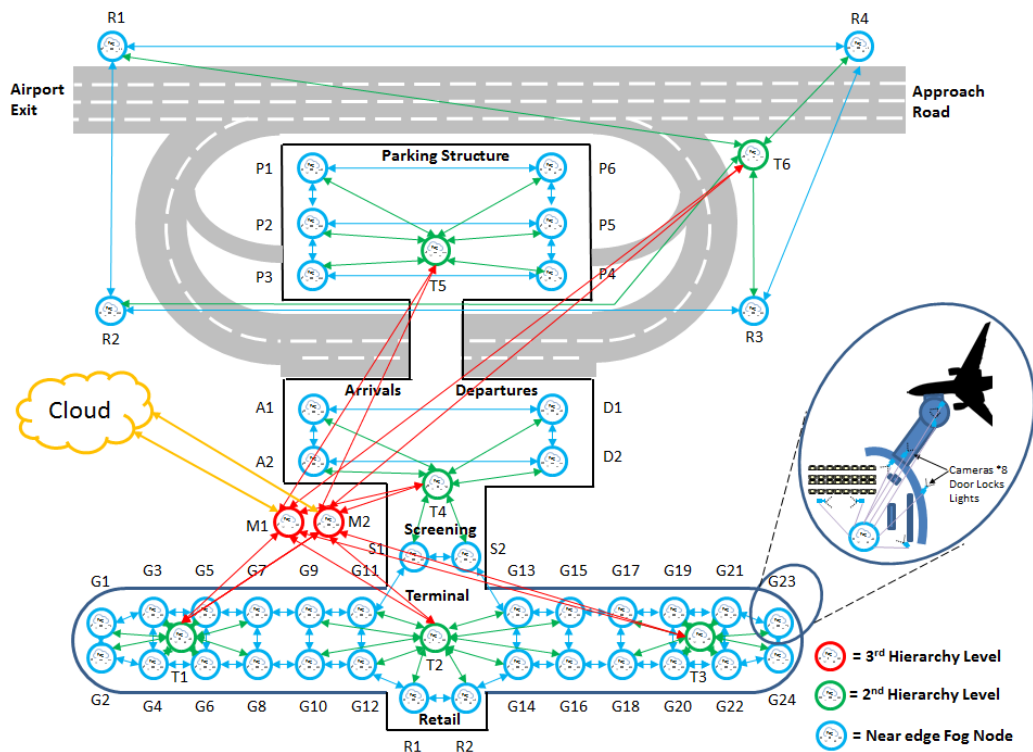
# OpenFog architecture view with perspectives



# End-to-end use case: securing air travel



- Multiple locations need to work together
- Cameras important part of the system
  - 1 Tb/day/camera
- Immediate action needed
- Applications deployed: risk scoring, vehicle capture, baggage capture



*Airport terminal provisioned with a hierarchy of fog nodes*

# Next steps for the OpenFog architecture

- Next level of detail:
  - Detailed specifications, APIs
  - Testbeds, architecture demonstrations
  - Additional use cases
- Next level of openness and interoperability:
  - Partnership with ETSI Multi-access Edge Computing (MEC)
- Steps towards technology certification



# OpenFog reference architecture: a baseline document

- Unified vision of the architecture for enabling exciting future applications
- First step in creating new industry standards
- Requirements
  - E.g., pillars: security, scalability, openness, autonomy, reliability & serviceability, agility, hierarchy, programmability
- Touching upon every part of fog supply chain



Industry commitment towards  
cooperative, open, interoperative fog systems



# Thank you!

Download the OpenFog Reference Architecture  
at

[www.OpenFogConsortium.org/RA](http://www.OpenFogConsortium.org/RA)

[info@OpenFogConsortium.org](mailto:info@OpenFogConsortium.org)



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