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

Barcelona Supercomputing Center (Centro Nacional de Supercomputación) · IEEE ComSoc (IEEE Communications Society) · IoT Acceleration Consortium

Founders

ARM · Dell · Microsoft · Cisco · Intel · Princeton University

Contributing Members

AT&T · Foxconn · Sakura internet · GE · Hitachi · Schneider Electric · Shanghaitech University

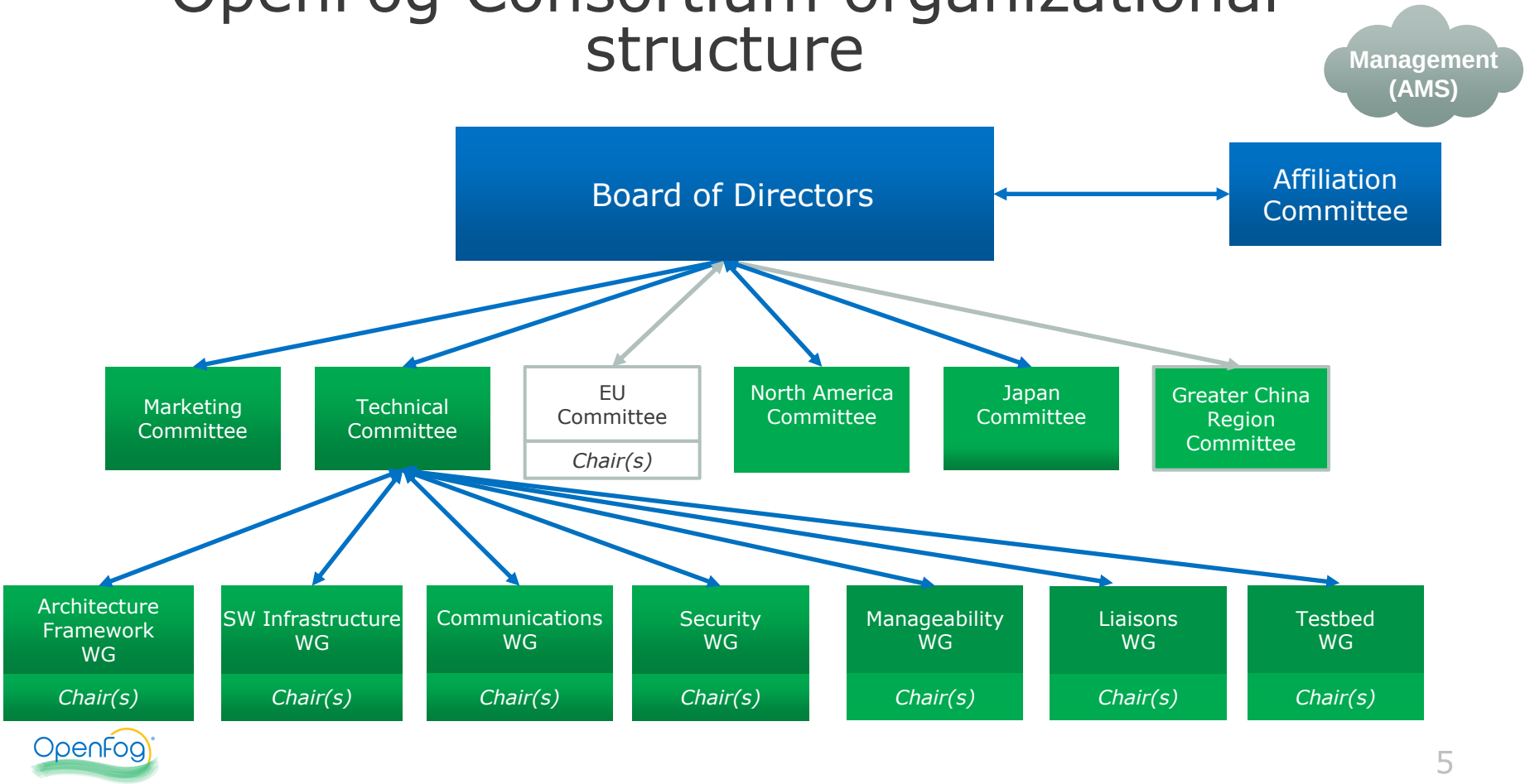
California Institute of Technology · Fujitsu · Foghorn · Toshiba · nebbiolo technologies (pioneers of fog computing) · Kii · imec · TTTech · ASU · Vanderbilt University · P/A · DenverSouth (Economic Development Partnership) · SUTD (Singapore University of Technology and Design) · Università di Pisa · CTC (Challenging Tomorrow's Changes) · Boulder · Technische Universität Dresden · Prismtech · rti · LGS Innovations · USC · III (財團法人資訊工業策進會, Institute for Information Industry) · MARSEC · The University of Georgia · OSIsoft · NGD systems (Bringing Intelligence to Storage) · National Taiwan University · NEC · relayr. · SRC (Redefining possible) · ABBALab · Mitsubishi Electric · OpenFog · Indian Institute of Technology Roorkee · NTT Communications · Aalto University · 國立交通大學 National Chiao Tung University · IIJ (Internet Initiative Japan) · Wayne State · ITRI (Industrial Technology Research Institute)

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

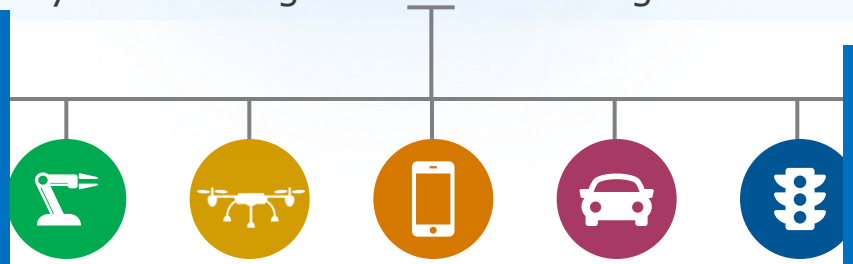
FOG COMPUTING

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

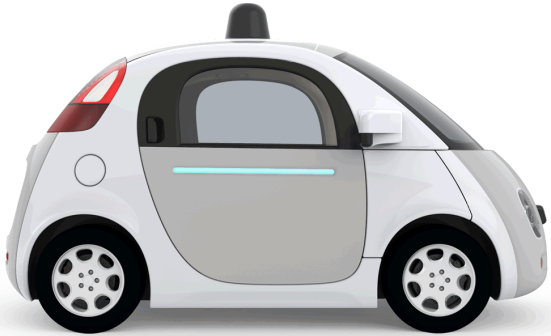
(not just at the edges)

Converged cloud/fog platforms and services

(not just isolated edge computing devices / apps)

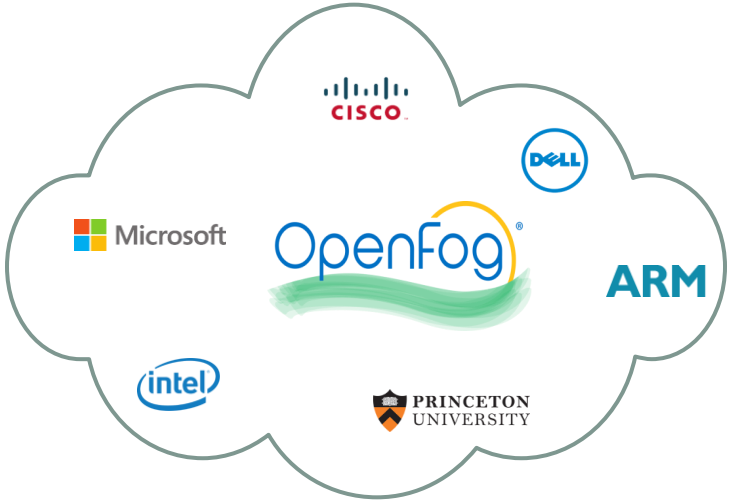
OpenFog

Fog enables advanced IoT, 5G & AI use cases



OpenFog

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

OpenFog

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

OpenFog reference architecture: core principles

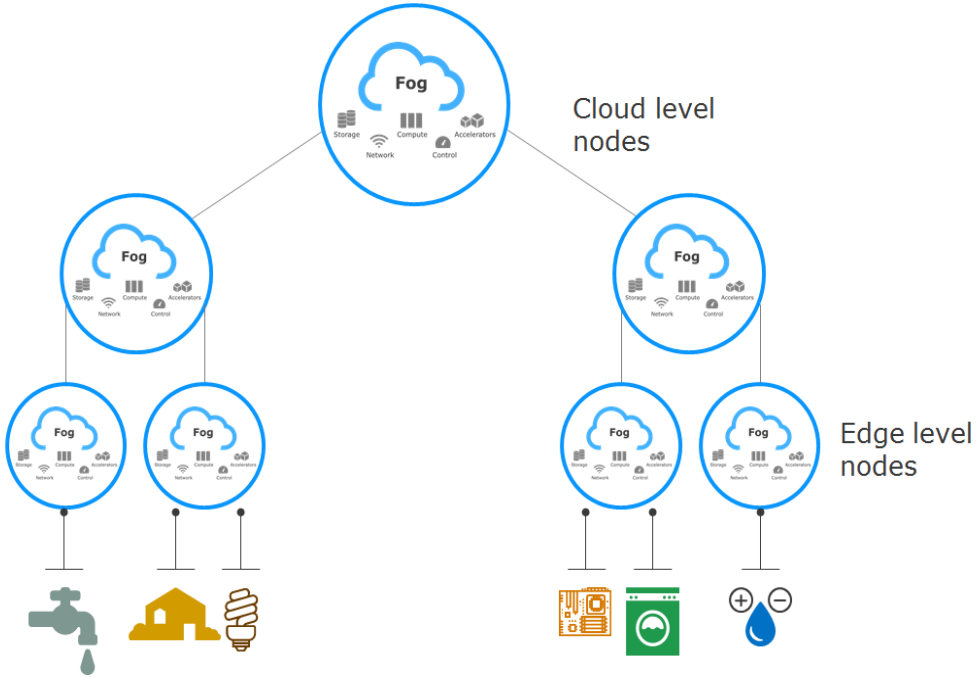
Requirements to every part of supply chain:

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

Security	Scalability	Openness	Autonomy	RAS	Agility	Hierarchy	Programmability
• 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

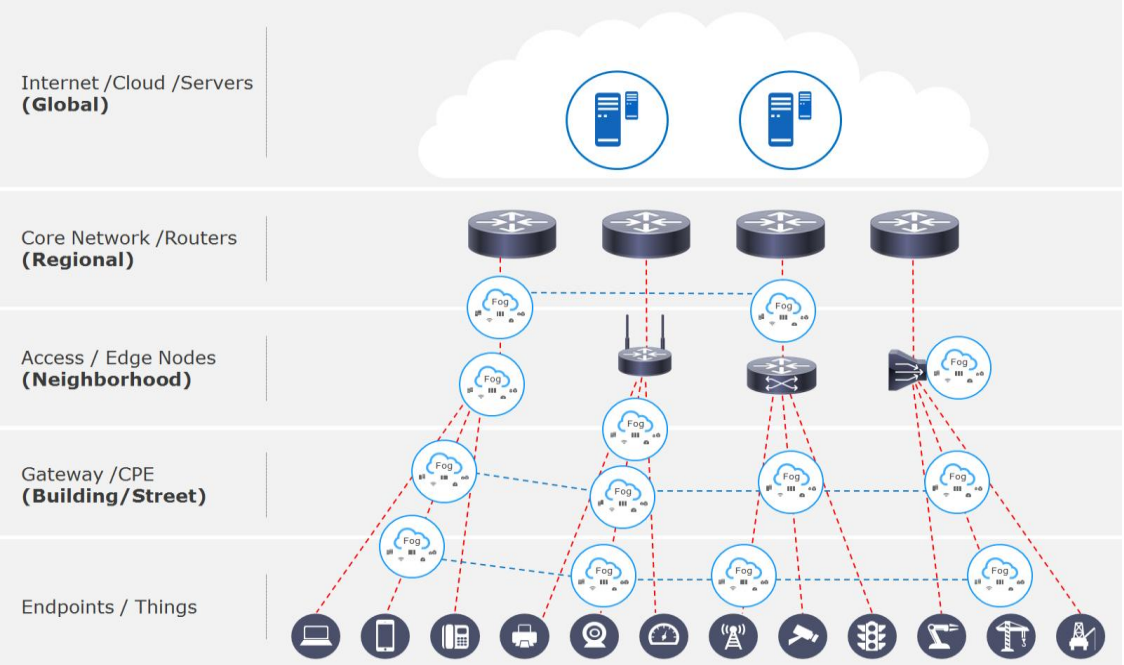
Multi-tier deployments

- 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

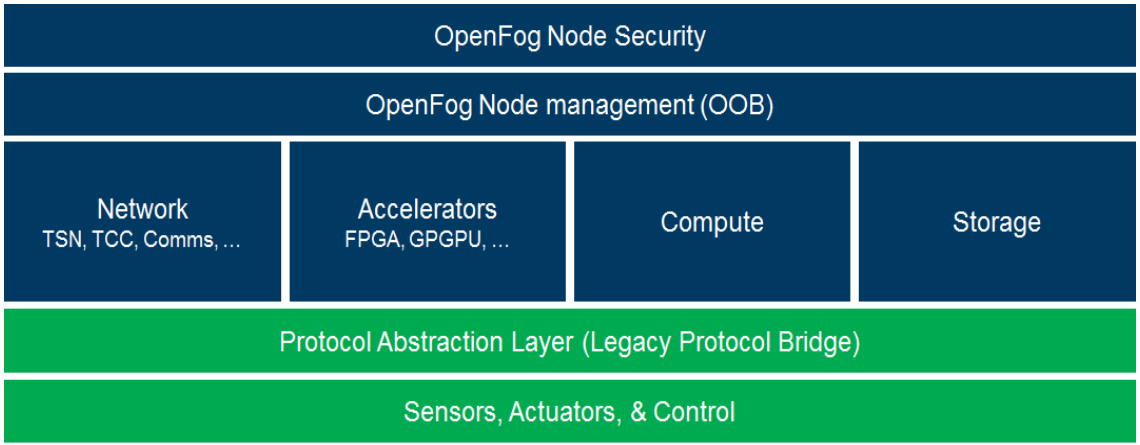
Supporting software

Platform

Fog nodes

Lowest level of architecture description: node view

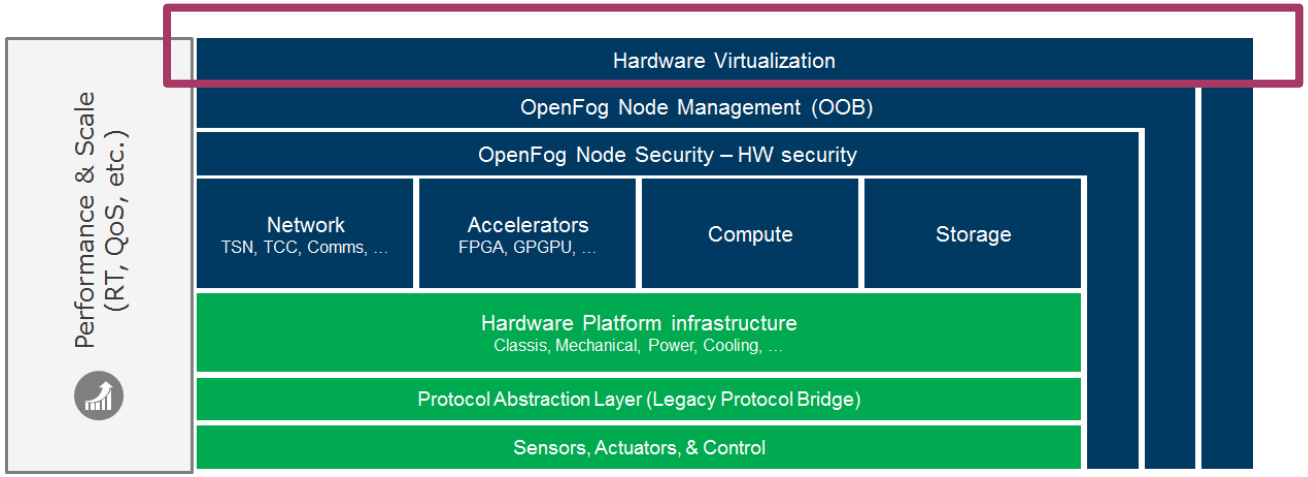
- Targeted at chip designers, silicon manufacturers
- Architecture ideas, design considerations from IoT/sensor, mobile, server computing nodes



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



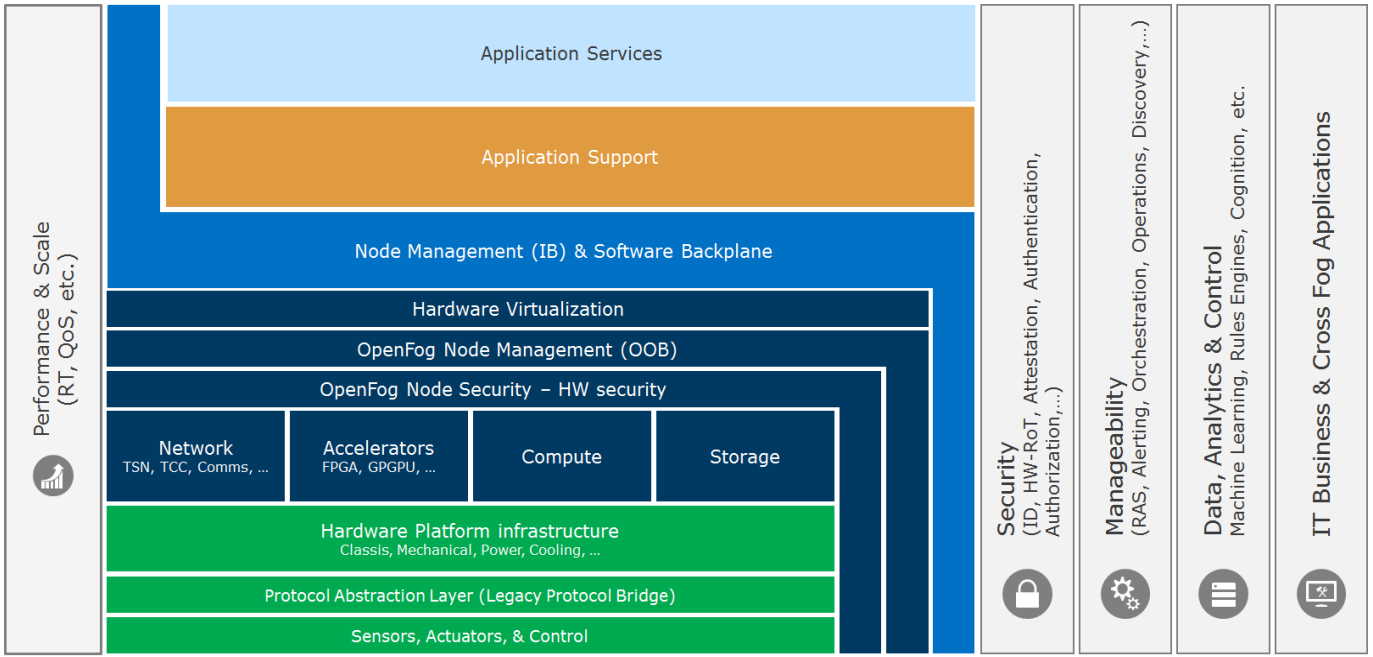
Fog system architecture

Software architecture view

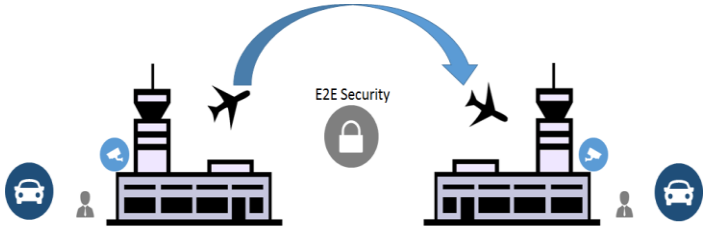
- Targeted at software architects, solution designers
- Software backplane: drivers, OS, communication and security services
  - ➢ Under active development
- Fog-specific application services: core, analytics, integration services

Fog software architecture

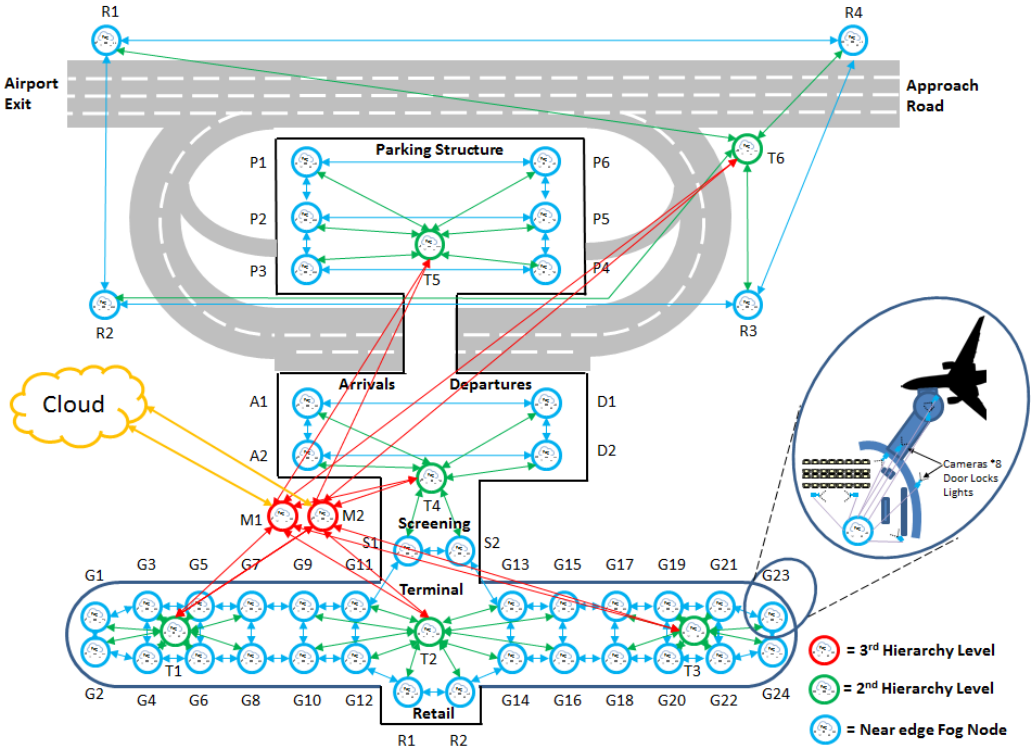
OpenFog architecture view with perspectives



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

Download the OpenFog Reference architecture at

www.OpenFogConsortium.org/RA

info@OpenFogConsortium.org

www.OpenFogConsortium.org