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

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PRINCETON UNIVERSITY

Contributing Members

AT&T
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nebbiolo technologies

Affiliations

Barcelona Supercomputing Center
IEEE ComSoc
IoT Acceleration Consortium

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

Board of Directors

Affiliation Committee

Marketing Committee

Technical Committee

EU Committee

North America Committee

Japan Committee

Greater China Region Committee

Architecture Framework WG

Chair(s)

SW Infrastructure WG

Chair(s)

Communications WG

Chair(s)

Security WG

Chair(s)

Manageability WG

Chair(s)

Liaisons WG

Chair(s)

Testbed WG

Chair(s)
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)

**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)

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

Requirements to every part of supply chain:

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

- Security
  - Specific to deployment needs
  - Trust
  - Attestation
  - Privacy

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

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

- Autonomy
  - Flexible
  - Cognition & agility
  - Value of data

- RAS
  - Reliability
  - Availability
  - Serviceability

- Agility
  - Tactical & strategic decision making
  - Data to wisdom

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

- Programmability
  - 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

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<thead>
<tr>
<th>Applications</th>
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<tbody>
<tr>
<td>Supporting software</td>
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<tr>
<td>Platform</td>
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<tr>
<td>Fog nodes</td>
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<tr>
<th>Performance &amp; Scale</th>
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<tr>
<td>(RT, QoS, etc.)</td>
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<table>
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<tr>
<th>Security</th>
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<tr>
<td>(ID, HW-RoT, Attestation, Authentication, Authorization,...)</td>
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<th>Manageability</th>
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<tr>
<td>(RAS, Alerting, Orchestration, Operations, Discovery,...)</td>
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<th>Data, Analytics &amp; Control</th>
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<tr>
<td>Machine Learning, Rules Engines, Cognition, etc.</td>
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<th>IT Business &amp; Cross Fog Applications</th>
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[Image of a diagram showing the multi-layer architecture with layers labeled Applications, Supporting software, Platform, and Fog nodes, and boxes labeled with different concerns and examples like Performance & Scale, Security, Manageability, Data, Analytics & Control, and 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
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

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OpenFog Consortium
A Growing, Global Ecosystem

Founders
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- Dell
- Microsoft
- Cisco
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Contributing Members
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