Elements of an Open, Interoperable Architecture for Fog

Presented by Members of the OpenFog Architecture Team
October 30, 2017

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Agenda

- Welcome
- Fog Overview
- OpenFog Reference Architecture
- Communications Topics
- SW Infrastructure and Messaging
- Security Topics
- Management and Orchestration
- Q&A

Chuck Byers – Cisco (Moderator)

Maria Gorlatova – Princeton University
Jim White – Dell and EdgeX Foundry
John Zao - National Chiao Tung University
All
Overview of Fog Computing

• Fog Computing is a system level architecture that extends the Compute, Networking and Storage capabilities from the Cloud to the Edge of IoT networks

• Think of it as the full capabilities of the Cloud, but closer to the ground

• It is a superset of other edge architectures (like MEC or IIC), extending to multiple topologies, modes, functions and verticals with advanced capabilities

• Cisco projects that 40% of IoT traffic will eventually pass through Fog nodes

• Fog systems need to be open and interoperable for the market to succeed – the OpenFog Consortium and other bodies are hard at work on that

• Some key capabilities of Fog that are essential to IoT:
  • Low Latency
  • Bandwidth Efficiency
  • Security
  • Scalability
  • Interoperability
  • Manageability
  • Autonomy & Agility
  • Hierarchical Organization
  • Programmability
  • Reliability & Robustness

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Verticals and IoT Use Cases

- **Transportation**: (Smart highways, Connected / autonomous vehicles, PCT/Rail, UAV ground support, Parking)
- **Utilities**: (Smart grid, Smart meters, Water distribution, Sewer monitoring, Energy management, Renewables)
- **Smart Cities / Smart Buildings**: (City-level Fog, Smart buildings, Lighting, Emergency services, Sanitation)
- **Manufacturing**: (Plant automation, Robotics, Analytics, Smart supply chain, QC, Distribution, Logistics)
- **Retail / Enterprise**: (Smart store, Branch-in-a-box, Visual security, Asset tracking, Signage, Analytics, Thin clients)
- **Service Providers / FaaS**: (Smart networks, Fog-as-a-Service, Media caching, Microcells, Resiliency, MEC)
- **Oil / Gas / Mining**: (Exploration, Rig-in-a-box, Production monitoring, Pipeline control, Refinery control)
- **Health Care**: (Continuous patient monitoring, Aging in place, Cognitive assistance, Exercise)
- **Agriculture**: (Irrigation, Crop monitoring, Yield assessment, Pest control, Autonomous equipment)
- **Government / Military**: (Homeland Security, C4ISR, Autonomous vehicles, Electronic warfare, Connected fighter)
- **Residential / Consumer**: (Home automation, Residential networking, Security, Social media, Haptics, AR, Games)
- **Hospitality**: (Front desk, Bell robots, Entertainment, Security, Cruise ships, Campgrounds, Dormitories)

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Transforming Data into Wisdom in IoT Networks

Wisdom (Scenario Planning)

Knowledge

Information

Data

Sensors & Actuators

More Important

Business Benefit

Less Important

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www.fogworldcongress.com
Centralized vs. Distributed Compute for IoT?

**More Distributed**
- Slide Rules & Adding Machines
- PCs and Workstations
- Smartphones & Tablets
- Fog Computing & MEC

**More Centralized**
- Timeshare Computers
- Internet, WWW, Search
- Cloud Computing

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Architecture

Chuck Byers
Principal Engineer – Cisco Corporate Strategic Innovation Group
Co-Chair, OpenFog Technical Committee / Co-Chair OpenFog Architecture Work Group
Need for Fog

Can’t run everything in the Cloud. There are latency, mobility, geographic focus, network bandwidth, reliability, security and privacy challenges.

Can’t run everything in intelligent endpoints. There are energy, space, capacity, environmental, reliability, modularity, and security challenges.

By adding layers of Fog Nodes, applications can be partitioned to run at the optimal network level.
Pillars of Fog Computing

- **Security**
  - Trust
  - Attestation
  - Privacy

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

- **Open**
  - 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

- **Programmable**
  - Programmable SW/HW
  - Virtualization & multi-tenant
  - App Fluidity

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Communications

Maria Gorlatova, Ph.D
Associate Research Scholar, Princeton EDGE Lab
Co-Chair Emeritus, OpenFog Communications Work Group
Communications and Networking in OpenFog: in all Cross-cutting Concerns

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Important Communications Scenarios

• Supporting distributed computing and storage in fog
• Ultra-low-latency scenarios
• Emerging applications, including:
  ➢ 5G
  ➢ Autonomous driving
  ➢ Augmented and virtual reality (AR/VR)
• Brownfield deployments
OpenFog Approach to Communications

- Plane separation:
  - Data, control, management plane

- Directions of communications:
  - Fog node to fog node
  - Fog node to cloud
  - Fog node to device/thing

- Aligned with the core architectural pillars
- Aligned with existing protocols

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Scenarios → Capabilities

• Baseline capabilities, wired and wireless: e.g., stationary, no real-time needs
  ➢ **Smart home**, simple in-fog data processing, …

• Modular layers of capabilities on top of the baseline, to allow:
  ➢ Very high throughput - for **video surveillance, autonomous driving, big data** upload to cloud
  ➢ Multicast communications – for **movie streaming, AR/VR**
  ➢ Mission critical needs – for **autonomous driving safety, e-health, oil and gas**

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Software Infrastructure And Messaging

Jim White
Distinguished Engineer, Software Architect, Dell Technologies
OpenFog Software Work Group
Software Architecture View

Software delivering use cases: VMs, containers, microservices, runtime apps, ....

Provide support for services databases, message brokers, service registry, shared resources

Backplane: OS, drivers, firmware, virtualization/container infra

Management of the app support/app service: Resources, security, comms, SLA/TLA, orchestration

Management of the Fog Node: Node resources, base security, comms, telemetry, control, failover, manageability

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Example Service v. Support

2 aspects: registry & communications

Other aspects:
- App service availability & service
- App service lifecycle
- App service operation management
- Software execution abstraction

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Software & Management Architectures Require Understanding of Fog Node Types

**Physical**

**Logical**

**Virtual**
Fog Security: Challenges

**Interoperability**
- Work as a Shim between Clouds & Things
- Tolerate Diversity in Devices & Capability
  - Smart Appliances
  - Wearable & Mobile Devices
  - Industrial & Grid Stations
  - Surveillance & Monitoring Systems
- Accommodate Disparity in Interfaces
  - Wireless: WLAN/ WPAN
  - Vehicles: VAN
  - Powerline: PLC
  - Automation: CIP
- Compatible with Different Operation Paradigms
  - Client-Server Pull
  - Publish-Subscribe Push

**Incrementality, Scalability & Mobility**
- Private/Public/Hybrid Fogs
- Multi-Domain Security Management
- On-Demand Fog Deployment
- IOT Plug-n-Play & Roaming

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Fog Security: Approach

- Multi-tier Multi-facet Approach to Fog Security

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OpenFog Security Aspect: Node Security

- **Platform Security**
  - Hardware Root-of-Trust
  - Crypto Accelerators
  - Standardized Crypto Functions
    - Crypto Function Task Group under Security WG
  - Security Evaluation
    - Adopting CC & ISASecure approach

- **VM Security**
  - Hypervisor Security
  - Trusted Boot

- **Trusted Computing**
  - Distributed Trusted Execution Environments (DTEEs)
  - Tradeoff between Security & Performance

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OpenFog Security Aspect: Network Security

- **Communications Security**
  - All comm run through TCP/UDP/IP stack
  - Node-to-Cloud
    - WS* / REST over TLS
  - Node-to-Node
    - HTTP over TLS
    - COAP over DTLS
  - Node-to-Device
    - IP Adaptation
      - WLAN/WPAN: 6LowPAN
      - PLC: PRIME IPv6 SSCS
      - Automation: CIP EtherNet/IP

- **Services Security**
  - NFV Security Appliances
  - SDN Service Provisioning

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OpenFog Security Aspect: Management

- **Management Infrastructure**
  - Compatibility & Integrability with IoT/M2M standards

- **Identity Management?**
  - Node & Device Identifiers
  - VM Identifiers
  - Task & Process Identifiers

- **Credential & Trust Management**
  - Management Infrastructure
  - New technologies?

- **Policy Management & Enforcement**
  - AAA vs. Monitoring Policies
  - Management Infrastructure

- **Closed-Loop Dynamics: On-line Behavior Learning & Real-time Response**

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Service Management and Orchestration for Fog
Introduction
Why Fog Computing is important now…

Time
- Real-Time processing
- Low latency decisions
- Millisecond reaction time

Distance
- Edge closer to User
- User closer to Service

Efficiency
- Pooling for local resources & control
- Sharing peer capabilities
- Delegation of authority/local elected leader

Cognition
- Awareness of client centric objectives
- Privacy/reliability trust factors in the cloud
- Shortening communication path (security)

Service Management
- Contractual adherence to service level agreements
- Orchestrated and coordinated delivery of services

Context
- Trace/Track of end-to-end service
- Root of Trust

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Evolution of Fog Computing

- **Central Hub & Spoke:** Rudimentary Management
- **Mesh & Interconnected:** Active Management
- **Local Edge Cloud – Fog – DC Cloud:** Orchestrated Management
- **Autonomous & Distributed Fog:** Autonomous, Composable, Distributed Management

- Hub and Spoke, Centralized System
- Mesh Interconnected Edge
- Load Balanced, Static Fog/Edge-Local Cloud & DC Cloud
- Dynamic Distributed Fog

Orchestration & Service Management

- Nothing
- Best Effort
- Intelligent Placement
- Context, Individual Autonomy, Orchestrated SLA

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Scheduling vs. Orchestration

**SCHEDULING**
- ... can manage infrastructure resources and efficiently schedule/provision service request
- ... have the ability to understand the infrastructure, gain insight through telemetry and in-band/out-of-band metrics and via agents.
- ... have the ability to intelligently schedule and provision resources, place VM’s, containers and workloads
- ... have the ability to define service delivery regions, availability zones & tenant isolation (service delivery objectives)

**ORCHESTRATION**
- ... can enforce tenant service level agreements by dynamically readjusting resources and intelligently responding to events
- ... have the ability to create and maintain context between the tenant’s services and the resources allocated/reserved for fulfillment
- ... have the ability to manage failures and resolve service degradation real-time
- ... have the ability to deliver to measurable and contractually observable service level objectives

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Not Aware of Service Level Objectives

Aware of Service Level Objectives

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Orchestration

The capacity to gain an accurate and deep intuitive understanding:
- Static, Real Time, Runtime Data
- Metrics
- Telemetry (IB/OOB)
- Messaging
- Errors
- Status
- Notification
- Resource/Asset Management

The ability to direct, regulate, command or manage:
- Controllers
- Agents
- Interfaces
- API(s)
- Functions

The circumstances that form the setting for an event and in terms of which it can be fully understood – Sense and React:
- Chaining & Linking
- Self-Awareness & Autonomy
- Tracking & Tracing
- Sensors & Interfaces
- Location
- Authentication & Authorization

The capability to enact intelligent decisions with control and context:
- Automation
- Intelligence
- Governance
- Compliance
- Auditing
- SLA/SLO
Resource Level Intelligence/Autonomy

...at the edge or in the cloud...

Describes the resource capability, identity, location, capacity and features. Includes Analytics for actionable intelligence.

Describes externally programmable resource features for rapid allocation – can include value, in terms of cost for billing, metering and measurement etc...

Describes the resource reservation, allocation, lock and runtime status as well as any other relevant policies of operation, self preservation and self-management.

Describes the resource function, reputation and actual capability based on age, use and other past usage factors.

PHYSICAL LANDSCAPE
Describes the advertised capabilities for the resource in terms of services.

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Thank You!

Any Questions??

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