Fog Computing Design Principles for Industrial IoT Applications

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IoT Trends & Challenges

- More data from more sources helps businesses make better decisions
  - Key is to aggregate and analyze data from multiple IT and OT sources in a timely manner

- Where should this aggregation and analysis occur?
  - Depends on the characteristics and requirements of specific vertical

Source: Gartner, IDC
Example: Industrial IoT for Manufacturing
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1. SCADA
2. Sensor Fusion
3. Edge Server
Example: Industrial IoT for Manufacturing

1. SCADA
2. Sensors
3. Sensor Fusion
4. Cloud
Drawbacks of Cloud-Centric IoT Solutions

- Centralized Computing
- Requires Internet Access
- Large Latency
- Limited Backhaul Capacity
- Privacy, Security, Cost
Fog Computing for Enabling Industrial IoT
Octopus body is not a separate thing that is controlled by its brain

Each arm can move, touch, and exert force without oversight from the brain

Results in faster actions, enables more complex tasks
Octopus Distributed-Computing Architecture

Actions requiring low latency, fast decision making

Fine tuning of complex actions initiated by brain

Complex actions requiring wider coordination among various compute and sense elements
Octopus Computing Applied to Real World

IoT data is sent to Cloud for analysis

IoT data can be analyzed at multiple locations between Cloud and Assets
IoT data is sent to Cloud for analysis

Anywhere along Cloud-to-Thing Continuum
Fog-based Industrial IoT for Manufacturing

Fog exploits north-south as well as east-west connections to enable distributed & coordinated analytics.
Defining Fog Computing

Selective distribution of analytics, control, and decision making anywhere in the continuum between Clouds and Things

- Relocates computing closer to users
- Enables hierarchical computing to enhance scalability
- Provides local intelligence for resource-constrained devices
- Services for OT x IT integration
Fog Computing Architecture and Design Principles
Layered Architecture View of an IIoT System

Fog Cluster Hierarchy

- Business Support: Large-scale analytics
- Operational Support: Operational analytics and supervisory control
- Monitoring and Control: Closed-loop control for asset operational management

Source: OpenFog Consortium
Fog Computing Deployment Models

Enterprise Systems

Business Support

Operational Support

Monitoring & Control

Sensors & Actuators

Source: OpenFog Consortium
Key Constraints for Fog Design

- **Analytics Feasibility**
  - Availability of IoT Data and Compute Power
  - Application Latency Requirements

- **Analytics Effectiveness**
  - IoT Data Quality
  - IoT Data Aggregation

- **Infrastructure Feasibility**
  - Network capacity to move IoT data
  - Security, Privacy, Safety
Where to Host Analytics?

OT know-how is critical for analysis of right data at right place at right time

Analytics Distribution Cost Matrix

<table>
<thead>
<tr>
<th>Location</th>
<th>IoT Data Quality</th>
<th>IoT Data Aggregation Level</th>
<th>Network Load Created</th>
<th>Compute Power Available</th>
<th>Latency</th>
<th>Security</th>
<th>Cost of moving IoT Data ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud</td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
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<tr>
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</tr>
</tbody>
</table>

Legend:
- Poor
- Fair
- Good
- Excellent
Fog Computing Case Studies
A. Manufacturing – Real-time Condition Monitoring

PLCs
A. Manufacturing – Real-time Condition Monitoring

Small-scale Validation Phase

Cloud

FOG

Edge

ML requires lot of computing and network resources; Difficult to scale the initial deployment

Calculate high level KPIs

ML Anomaly detection

ML Model Building

PLC

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A. Manufacturing – Real-time Condition Monitoring

Fog-enabled Scale-out Deployment

Cloud

FOG

Edge

Compute high level KPIs

ML Model Building

All raw data; huge

PLC

Compute KPIs

ML Anomaly detection

FOG provides tradeoff between compute and network resources
B. Manufacturing – Event Driven Monitoring

After-furnace PLC (Red light)

PLCs
Video evidence of the anomalous events is useful to get better “awareness” for continuous improvements but owing to huge data size, it’s difficult to scale the Edge-based solution.
B. Manufacturing – Event Driven Monitoring

Fog-enabled Scale-out Deployment

Cloud

FOG

Edge

- All recorded video data; huge
- ML Model Building
- Video On-demand Service
- ML Model Building
- ML Anomaly detection

Compute high level KPIs

FOG has enough capacity to provide video on-demand service for company-wide scale
C. Transportation – Fleet Condition Monitoring

- Individual trucks in a fleet continuously transmit diagnostic data to the cloud for condition monitoring
- Amount of data can be dynamically adjusted for tradeoff between information content and transmit volume
D. Transportation – Data Aggregation in Fleets

- Individual trucks in a convoy continuously transmit diagnostic data to the cloud for condition monitoring
- Fog Computing can aggregate data from multiple trucks and thus reduce cost and improve data reliability

### Existing Operation

- Each truck transmits to cloud via WAN
- Satellite used in cellular dead-zones
- High WAN data cost

### Fog Enhanced Solution

- Each truck transmits to fog node via LAN
- Fog node aggregates, compresses data
- Single WAN connection from fog node

### Transmitted Data Volume

- 4 truck simulation
- The fog functionality shifts across trucks based on cellular coverage
Gather sensor info from several vehicles and analyze environmental condition. Road condition (hole/dropped object/snowy road), congestion, pedestrian, …

Notify detail condition to Administrator

Alarm or Warn to other vehicle around the area

Upload sensing information when edge detects an anomaly. Sensor info: Image, velocity, acceleration, vibration, …

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Conclusion
Fog Computing is essential for scalable real-world deployments.

Domain expertise is critical for realizing efficient implementations of Fog for various industrial IoT applications.
Thank You