Integrating Mobile Internet of Things and Cloud Computing towards Scalability: Lessons Learned from Existing Fog Computing Architectures

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Mobile Internet of Things (MLoT)

MLoT – Cloud integration
  - Advantages/Issues
  - Similar work in literature

Fog computing background
  - Architecture analysis
  - Components description

Taxonomy and discussion

Research directions
Development of **Smart Objects** towards *Cyber Physical System (CPS)*:
- Sensors
- Actuators

**Trends** (by 2025):
- Enormous amount of data
- Mobile wireless connections
- Devices connected: 1 trillion
- M2M communications: 100 millions

**Challenges** in MIoT applications:
- Mobile connectivity
- Openness
- Scalability
MloT/Cloud Integration - Advantages

- **Cloud advantages:**
  - Resource availability
  - Costs (pay as you go model)
  - Efficiency
  - Scalability (no more worst-case planning)
  - Industrially mature technology

- **Cloud-MIoT perfectly complementary:**
  - Extending Cloud to real-world scenario
  - Industrially-feasible MIoT applications (critical contexts)
Cloud inefficiencies:
- Sensors high sample rate → number of connections
- Great amount of raw data
- Wrong Cloud usage
Other Literature Research

- **Cloudlet:**
  - Cluster of multi-core computers
  - Cloud data centers towards end devices
  - Real-time, location-awareness

- **Edge Computing:**
  - Applications, data and services moved towards end points
  - Traffic, cost, latency, security/privacy, scalability

- **Follow-Me Cloud (NEC Lab.):**
  - Support technology for mobile Cloud applications
  - Ability to migrate network services
  - Network services follow users’ movements
- Computation moved **near the end devices**
- Common platform to deliver applications (**multi-tenancy**) 
- All different levels of the IT development involved 
- Easier **integration cloud-side**
Fog Computing Architecture
Local Sensing and Data Handling

**Motivations:**
- Data quality
- Relief further computation
- Constraint IoT devices
- Automatic data acquisition

**Components:**
- Data sink
- Data *aggregation*
- Basic data *filtering*
- Data *normalization*
Big/Small Data Processing

- **Big Data** analytics:
  - Cloud-side
  - Long-processing (Batch)
  - Long-term analytics
  - Heavy resources usage
  - Scalability, performance, cost

- **Small Data** analytics:
  - Fog-side
  - Low-latency processing
  - Near devices
  - Few/Significant data
  - Real-time, location-aware
### Actuation & Storage

#### Actuation:
- Real-time
- Location-awareness
- New applications (critical context)

#### Storage:
- Cloud-like resources
- Limited Cloud services
- Periodically upload
- Scalability, real-time
Fog Taxonomy

CLOUD

Security/Privacy  Scalability - Big Data  Data Quality

FOG

Data Quality  Interoperability  Real-time

Security/Privacy  Scalability - Geo-distribution  Mobility  Location-awareness

IOT

Security/Privacy  Mobility  Interoperability
Fog Taxonomy - Scalability

- **Big Data** scalability
  - Cloud-side
  - Long-term analysis

- **Geo-distribution**
  - Large area
  - Distributed nodes
  - Fog-side

- **Vehicular applications**
  - e.g. traffic policies
  - e.g. vehicles dense across regions
Fog Taxonomy – Data Quality

- Detect anomalies
- Real-time data actions
- Fault detection techniques

- Vehicular applications
  - Standard deviation on average values
  - Data thresholds to discard data
Fog Taxonomy – Location Awareness

- Fog-side
- Efficiency (resource consumption, network congestion)

Vehicular applications
- Areas of interest (roads, intersections, etc.)
- RSU infer system state
- RSU reaction (e.g. traffic light cycle, alarms, etc.)
Fog Taxonomy – Interoperability

- Heterogeneity in real-world scenario
- Computational power, resources lifespan, communications
- Performance issues
- Vehicular applications
  - On-board sensors, RSU, traffic lights
  - Multiple implementations
  - Policies from different authorities
Fog Taxonomy – Real-Time

- Low-latency reaction
- No Cloud interactions
- Data processing, Actuation

- Vehicular applications
  - Few ms for safety
- Wind Farm
  - Prevent turbine damage
  - Wind forecasting
Fog Taxonomy – Mobility

- MIoT intrinsic feature
- Device disappearance
- Device discoverability
- Hand-off

- Vehicular applications
  - Fast mobility support
  - Vehicles macro-points
  - Switch sub-network
Fog Taxonomy – Security/Privacy

- Pervasive requirement
- All layers involved
- Detect anomalies
- Protect data exposition

Vehicular applications
- Collisions avoidance
- Pervasive surveillance
- Image acquisition
- Vehicle movements patterns
Future Research Directions

- **Multi-level organization and interworking**
  - Group of nodes densely connected
  - Hierarchical or Cluster/Mesh organization
  - Load-balancing and scalability

- **Actuation capacity**
  - Cloud analysis vs. Fog actuation border
  - Different priority actions ➔ Level of interplay Cloud/Fog
  - e.g. Vehicular system:
    - Real-time actions inside vehicle - Long analysis outside vehicle

- **Efficient fog-cloud communications**
  - Algorithms/M2M-protocols for Fog/Cloud communications
  - Latency-tolerant applications ➔ Strong Cloud interplay
  - Latency-sensitive applications ➔ Exploit Small Data
Thanks for your attention!
Questions time…

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