Quality Attribute Concerns for Microservices at the Edge

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This material is based upon work funded and supported by the Department of Defense under Contract No. FA8702-15-D-0002 with Carnegie Mellon University for the operation of the Software Engineering Institute, a federally funded research and development center.

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DM20-0013
Agenda

Introduction
Challenges at the Edge
Architectures for the Edge
Microservices in Edge Systems
Microservices: Scaling Down at the Edge

Introduction
Who is TAS? Who am I?

Tactical and AI-Enabled Systems Initiative

- SEI Team of 10+ researchers, engineers, and domain experts working on edge technologies
- Focus on edge technologies since 2010
- Research & Customer Projects includes ML/AI, Networking, HMI, Data Analysis, Mobile Platforms, Context Awareness, Security, Resource Management

Marc Novakouski

- SEI Senior Engineer, 10+ years; Raytheon Senior Software Engineer, 8+ years
- Research & Prototyping work includes Microservices, Mobile Devices, Networking
- Customers include DHS, Army, Navy, USAF, USMC, SOCOM
What is this talk about?

We are good at building complex systems in safe locations doing relatively predictable things that change over time and may need to scale up.

- E-Commerce
- AI/ML applications
- Searching, Mapping, Social Media

We are less adept at building systems in unsafe locations in dynamic situations that change at a moment’s notice; i.e. at the “Edge.” In these situations, typically we fall back to simple, stand-alone solutions.

- Disaster recovery & First Responders
- Soldiers under fire

Q: How do we realize complex, dynamic solutions at the Edge?
A: By building to scale down, instead of up
Challenges at the Edge
What is “the Edge”? - 1

The **Humanitarian Edge**: First Responders & Humanitarian Aid

- **Cellular & Analog Infrastructure unavailable or limited**
- **Power unavailable or limited to generators or batteries**
- **Medical & Humanitarian needs prioritized; infrastructure repair typically later**
- **Compute unavailable or limited to mobile devices; limited reach-back**
- **Scope of mission unknown, includes survey, discovery, triage of issues**
What is “the Edge”? - 2

The **Tactical Edge**: Warfighters & Military Assets

- **Local infrastructure (if available)** ignored; comms provisioned/carried
- **Local compute** limited to mobile devices/vehicle-mounted nodes; limited reach-back
- **Mission goals** prioritized, equipment provisioned to support
- **Local power** ignored, carried/provided by assets; typically limited to mission duration
- **Scope of mission** well known, planned, provisioned; intel typically available for planning/mid-mission
### What are the Challenges?

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<th><strong>Humanitarian Edge</strong></th>
<th><strong>Tactical Edge</strong></th>
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| **Limited Network** | • Broken Infrastructure  
• Different networks in use (Bandwidth)  
• Coordination Required | • Military Hardware (rugged but limited)  
• Variety of Connectivity/Bandwidth limitations  
• Mission-specific data prioritization  
• Interference (terrain/opposing force) |
| **Limited Power**    | • Unknown Mission Duration  
• Limited battery/plug in resources | • All power carried/vehicle borne  
• Mission-specific power prioritization |
| **Limited Compute**  | • Limited/no reachback to cloud  
• Mobile devices only | • All compute carried/vehicle borne  
• Mission-specific compute prioritization |
| **Unsafe Conditions**| • Roads/Buildings/Infrastructure  
• Unknown Mission Scope  
• Limited attention  
• Prioritization of humanitarian equipment (medial, construction) over other resources (compute, power, network) | • Lives in danger  
• Focus on environment, adversaries; extremely limited attention  
• Loss of equipment (damage, jamming)  
• Adaptation to role changes (injury, casualty)  
• Security of equipment (zero-ize) |
Architectures for the Edge
Scenario Assumptions

Equipment
- A person operating at the edge will have a mobile device of some kind
  - Cell phone, raspberry pi, etc
- The mobile device will have limited connectivity & power
  - Spotty, low bandwidth, restricted access to cloud resources
  - Power should be rationed due to rare or unavailable charging opportunities

Mission
- A person operating at the edge will not have a full understanding of the situation
  - Situational awareness information is incomplete, old, or unavailable
- The mission will be dangerous
  - Teams will be small & distributed, if not individual
  - Majority of attention required to attend to situation
  - Possible damage to/loss of equipment, possible injury or loss of life

In general, a dangerous mission with limited compute, networking, power, manpower, and attention
Quality Attributes for the Edge

Compensating for Edge challenges requires specific Architectural Features

TAS experience at the Humanitarian & Tactical Edge suggest:

- Reliability
- Survivability
- Autonomy
- Adaptability
- Flexibility
- Distributability
- Openness
Quality Attributes for the Edge - Reliability

Reliability – As much as possible, a system at the edge must be able to perform in adverse conditions and environments. We define reliability to mean that the system is able to operate at the edge with minimum possible degradation from an ideal environment.
Quality Attributes for the Edge - Survivability

Survivability – Given the edge challenges, a system must be able to survive them. Survivability means that the system will continue to operate despite damage to hardware (compute, power, or networking) or the user.
Quality Attributes for the Edge - Autonomy

Autonomy – A system at the edge must have some level of intelligence in order to operate while the user is distracted by mission or environmental concerns. Autonomy means that the system can perform (some variable set of) actions on its own without user intervention.
Quality Attributes for the Edge - Adaptability

Adaptability – Things can change at the edge, moment to moment. Adaptability means the system is able to change what it’s doing at a moment’s notice, allowing it to adapt to drastically different conditions or mission needs. (Force multiplier w/ Autonomy)
Quality Attributes for the Edge - Flexibility

Flexibility – Limited devices at the edge generally only support limited computing tasks, driving mission specific assignment of equipment. Flexibility means the system can support multiple missions and switch between mission assignments as needed.
Quality Attributes for the Edge - Distributability

**Distributability** – Given the limited capability of mobile devices, a system at the edge will be most capable if it takes advantage of nodes working together. Distributability means that a system can operate across multiple edge nodes in concert.
Quality Attributes for the Edge - Openness

**Openness** – Given the challenges at the edge, and the historical mix of software and devices which are provided to soldiers and first responders at the edge, we cannot expect that one vendor or organization will solve all of these challenges. Openness means that the system must use well-defined, open, and well-supported interfaces and platforms so that any organization with an effective software or hardware solution can easily integrate their contribution with the system.
Nodes and Data Flow at the Tactical Edge

- Drones providing video to soldiers
- Drone video provided to processor on platform for AI processing
- Sensor data (RF, etc) provided to TOC for SA
- Data relay shuttling data as needed
- Data Fusion of enemy intel for soldiers in harms way
- Mission updates, enemy intel sent to front-line soldiers
- Targets fed to strategic assets

- Mission updates, enemy intel sent to front-line soldiers
Microservices: Scaling Down at the Edge

Microservices in Edge Systems
Why Microservices?

Microservices allow us to address the Quality Attributes of interest at the edge

- **Reliability & Survivability** – Monitoring, Quick restart, Hot Swap, Statelessness
- **Adaptability & Flexibility** – Statelessness, Small Footprint, Service Orchestration
- **Distributability & Openness** – Most platforms support Docker/TCP/UDP; Small Footprint; Standard Interfaces
- **Autonomy** – Sensor monitoring & adaptation

In short, they are ideal for scaling down and maintaining capability at the Edge
Example Technologies

Hardware Devices
- **Comms** – Iridium/Inmarsat; BT/WiFi Android MANET (e.g. Zello); Harris 117G/152a/163; Trellisware TW-400; Silvus Streamcaster 4200
- **Compute** – Mobile Phones/Tablets; Rasberry Pi; Beaglebone; Intel Compute Cards; Portable Embedded Computing Modules (Nvidia Jetson *)
- **Combined** – Persistent Systems MPU5

Software Technologies
- **Hosting** – Hypervisor (VMware, KVM, Xen, etc); Virtual Machines; Containers (Docker)
- **Orchestration/Coordination** – Kubernetes; ROS; DARPA Collaborative Operations in Denied Environments (CODE)
- **Middleware** – ZeroMQ; DDS; ActiveMQ; RabbitMQ
- **Encoding** – XML; CORBA; JSON; Protocol Buffers
Nodes and Microservice Allocation - Tactical Edge

**GPU-enabled SoC**
- Infrastructure
- Maps
- Bio-Medical
- Video
- Audio Record
- Visualization

**Limited SoC**
- Infrastructure
- Video Stream

**Cell Phone**
- Infrastructure
- Maps
- Bio-Medical
- Mobile Sensor Processing

**Mobile Server**
- Infrastructure
- Maps
- Visualization
- Cloud Reach back
- Full Sensor Processing
- Data Relay/Filtering

**Base Server**
- Infrastructure
- Mission Plan/Mission State
- Cloud Assets
- Full ML/AI capability

**Limited SoC**
- Infrastructure
- RF Sensor Data

**Mobile Server**
- Infrastructure
- Maps
- Mission Planning
- Cloud Reach back
- Full Sensor Processing
- Data Relay/Filtering
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