

Tactical Cloudlets: Moving Cloud Computing to the Tactical Edge

Grace Lewis, Ben Bradshaw, Sebastián
Echeverría, Dan Klinedinst, James Root, Keegan
Williams

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Motivation

Soldiers, first responders and field personnel operating in tactical environments increasingly make use of mobile systems for mission support

However, dynamic context, limited computing resources, disconnected-intermittent-limited (DIL), network connectivity, and high levels of stress pose a challenge for mobile systems in tactical environments



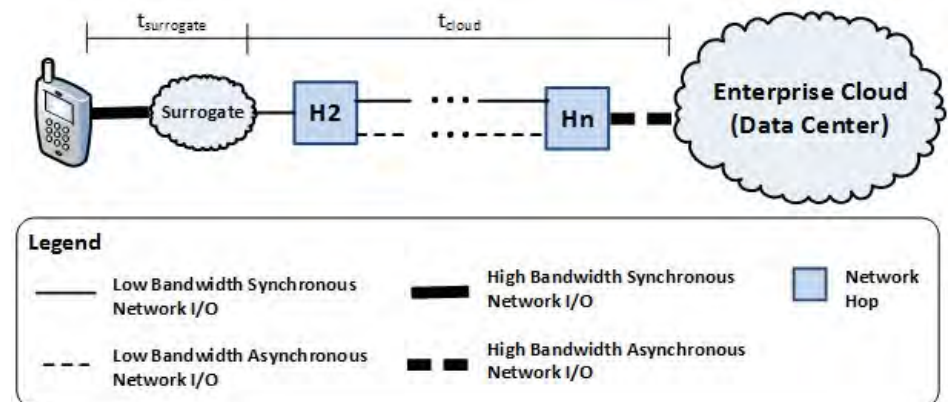


Cyber-Foraging

Cyber-foraging* is the leverage of external resource-rich surrogates to augment the capabilities of resource-limited devices

Two main forms of cyber-foraging

- Computation Offload
 - Offload of expensive computation in order to extend battery life and increase computational capability
- Data Staging
 - Improve data transfers between mobile computers and the cloud by temporarily staging data in transit on surrogates



* Satyanarayanan, Mahadev (2001). "Pervasive Computing: Vision and Challenges". IEEE Personal Communications (IEEE)

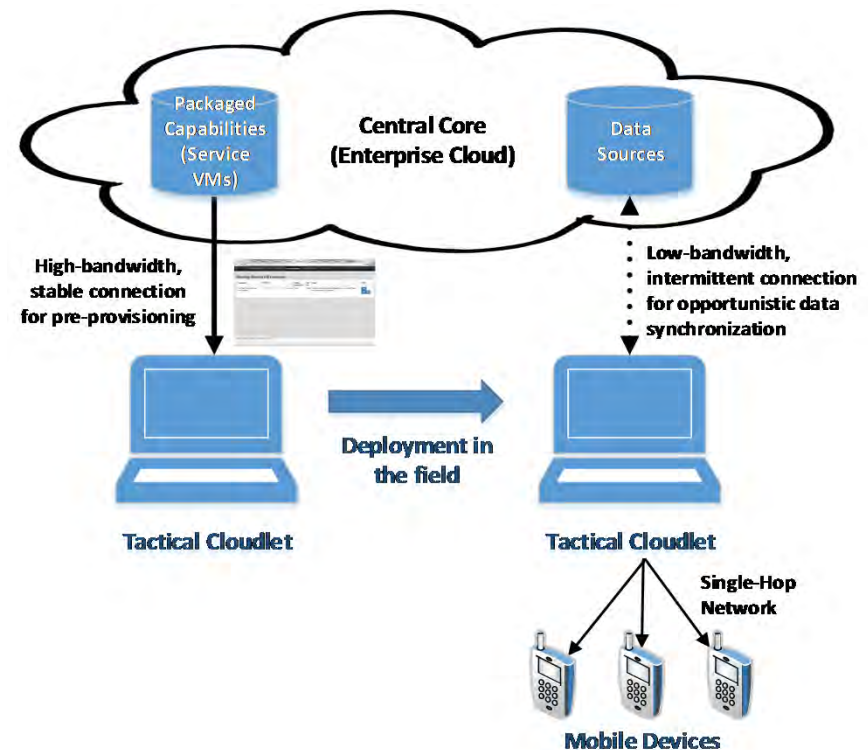




Tactical Cloudlets

Forward-deployed, discoverable, virtual machine (VM) based cloudlets that can be hosted on vehicles or other platforms and provide

- infrastructure to offload computation
- forward data-staging for a mission
- data filtering to remove unnecessary data from streams intended for dismounted warfighters
- collection points for data heading for enterprise repositories





Tactical Cloudlet Operations

1. Cloudlet Discovery

- Mobile device discovers proximate cloudlets
- Mobile device queries cloudlets for available capabilities
- (Optional) Mobile device downloads clients for capabilities (apps)
- Mobile devices uses cloudlet metadata to select the “best” cloudlet

2. Cloudlet Provisioning and Setup

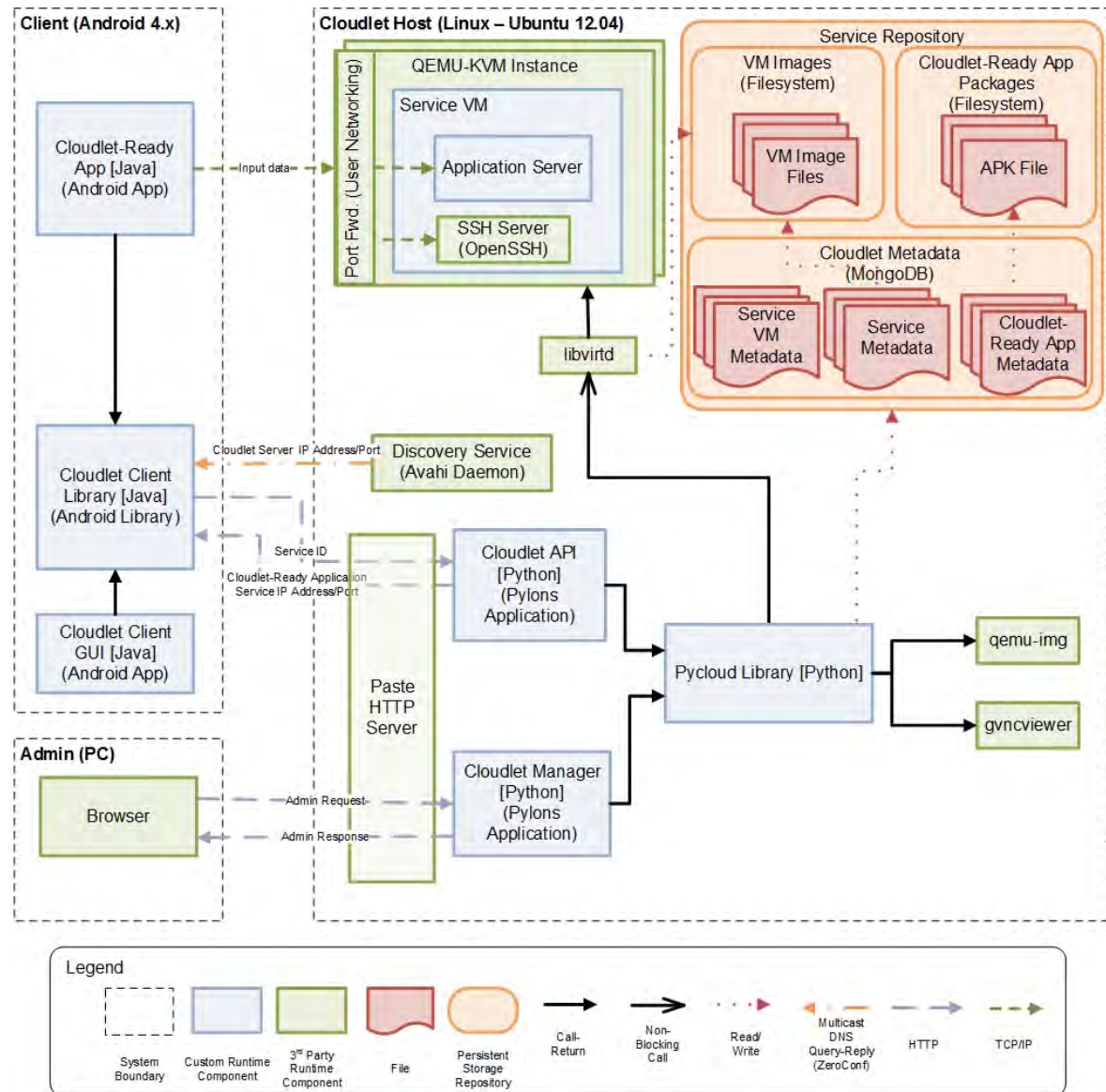
- Mobile device requests capabilities
- Cloudlet sets up capabilities on demand (shared and non-shared)
- Cloudlet informs mobile device that capabilities are ready

3. Application Execution

- Mobile device interacts with capabilities on cloudlet



Tactical Cloudlet Architecture





Tactical Cloudlets Features

Edge Characteristics Capabilities/Features	Intermittent cloudlet-enterprise connectivity	Mobility	Limited battery power	Dynamic missions	Limited technical skills in the field	Potentially hostile environments
<i>System Requirements</i>	<i>Disconnected operations</i>	<i>Quick response time</i>	<i>Low energy consumption</i>	<i>Ease of re-deployment</i>	<i>Ease of deployment</i>	<i>Trusted identities</i>
Pre-Provisioned Cloudlets with App Store	X	X	X	X	X	
Standard Packaging of Service VMs				X	X	
Optimal Cloudlet Selection	X	X				
Cloudlet Management Component				X	X	
Cloudlet Handoff/Migration		X		X		
Secure Key Generation and Exchange	X					X



Pre-Provisioned Cloudlets with App Store

Applications statically partitioned into a client and server

- Very thin client runs on mobile device (App)
- Computation-intensive server runs on cloudlet (Service VM)

Capabilities as services

- Service VM provides a self-contained capability and exposes a simple interface

Virtual machines as service containers

- VMs can be started and stopped as needed based on number of active users therefore providing scalability and elasticity
- Also enables legacy system reuse

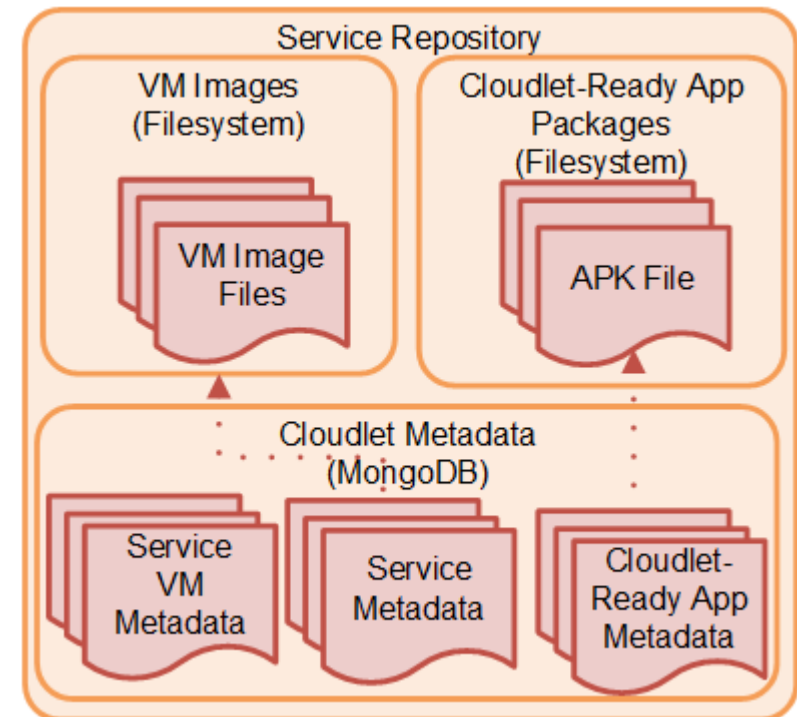
Request-Response interactions between clients and cloudlets

- Enables easy detection of failed communication between mobile devices and cloudlets
- Also minimal effect on mobile devices if computation needs to be restarted or migrated



Standard Packaging of Service VMs

- Standard format for Service VMs (.csvm) so these can be easily loaded from the cloudlet disk drive, an enterprise Service VM repository, a thumb drive, or a mobile device connected via USB or Bluetooth to the cloudlet
- Service metadata (JSON file): service ID, port, version, description, tags, shared/non-shared, minimum memory, ideal memory
- VM image files — one for the disk image and one for the state/memory image that contain a suspended Service VM





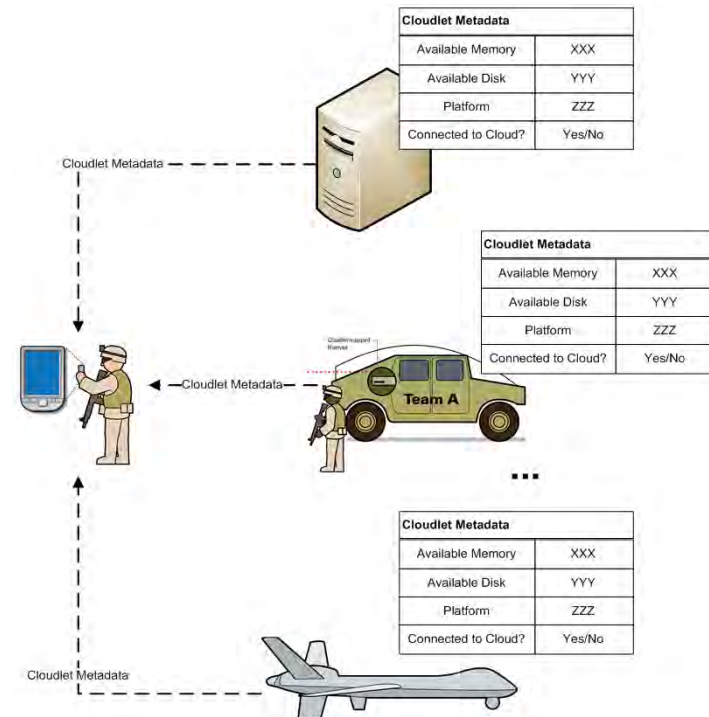
Optimal Cloudlet Selection

Useful when there is more than one cloudlet available

Architecture enables different algorithms to be plugged in

Implemented three algorithms

- CPU-Based Ranker: Selects the less loaded cloudlet based on CPU utilization
- CPU Performance Ranker: Also takes into consideration CPU speed
- Memory Performance Ranker: Takes into consideration free memory and CPU cache





Cloudlet Management Component

Lightweight, web-based interface that enables easy deployment and redeployment of capabilities

- Service VM creation, edit and deletion
- Service VM import and export
- Service VM Instance start, stop and migration
- Cloudlet-Ready App repository (i.e., app store)

The screenshot shows the Cloudlet Manager web interface. The top navigation bar includes links for Home, Available Services, Running Service Instances, Cloudlet-Ready Apps, Devices, and Sign out. The main content area features a welcome message and three primary actions: Available Services, Running Service Instances, and Cloudlet-Ready Apps. The 'Services' page displays a table of services with columns for Name, Service ID, Port, Service VMs, and Service Actions.

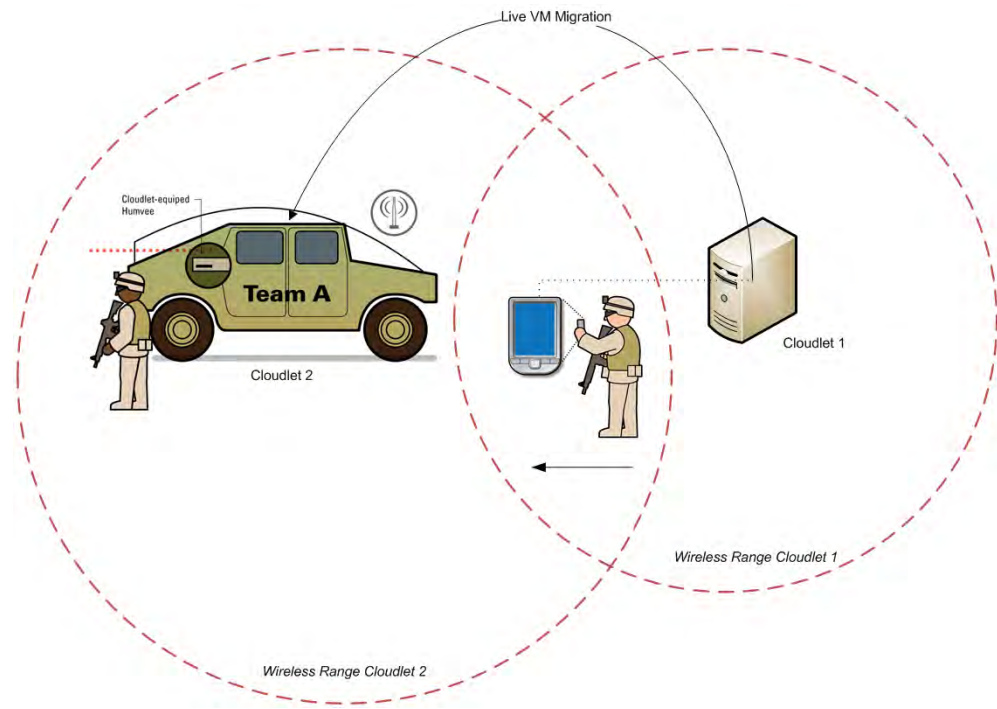
Name	Service ID	Port	Service VMs	Service Actions
Face recognition service	edu.cmu.sei.ams.face_rec_service_opencv	6789	+	[Refresh] [Stop] [Delete]
Object recognition service	edu.cmu.sei.ams.object_rec_service	9092	+	[Refresh] [Stop] [Delete]
Fluid service	edu.cmu.sei.ams.fluid_simulation_service	9093	+	[Refresh] [Stop] [Delete]
Speech Linux	edu.cmu.sei.ams.speech_rec_service	9001	+	[Refresh] [Stop] [Delete]



Cloudlet Handoff/Migration

Manual handoff enables scenarios in which a user is migrating capabilities from a fixed cloudlet to a mobile cloudlet to support field operations, as well as reintegration back to the fixed cloudlet

Goal in the future is to support automatic migration based on for example signal strength, load balancing or a more powerful surrogate in proximity





Secure Key Generation and Exchange (FY15 Work)

<p>Step 1: Bootstrapping</p> <ul style="list-style-type: none">• Generation of <i>Server Credentials</i> using IBE (Identity-Based Encryption)• Setup of <i>RADIUS Server</i> with <i>Server Credentials</i>	<p>Step 2: Pairing</p> <ul style="list-style-type: none">• Generation of <i>Device Credentials</i> using IBE• Transfer to device using Bluetooth or USB, plus visual confirmation• Transfer to <i>RADIUS Server</i>	<p>Device Credential Revocation</p> <ul style="list-style-type: none">• Automatic due to timeout: Bootstrapping requires setting up mission length• Manual due to known loss or compromise: Server Management component has revocation option
<p>Step 3: WiFi Authentication</p> <p><i>RADIUS Server</i> implements Wi-Fi WPA2-Enterprise 802.1X EAP-TTLS with PAP</p> <ul style="list-style-type: none">• Device receives server credentials and validates• Devices sends its credentials for validation	<p>Step 4: API Requests</p> <ul style="list-style-type: none">• Device exchanges encrypted messages with the server• Each exchange is validated against authorized device list	





Summary

Presented an architecture and implementation of cyber-foraging in tactical environments

Characteristics of tactical environments were mapped to system requirements for survivability and then to tactical cloudlet features

Next steps are

- Develop and evaluate a set of rankers for different service characteristics
- Support automatic/opportunistic migration
- Architectures for data staging
- Integration with DTN (Delay Tolerant Networking) to address DIL environment challenges

**Available on GitHub as KD-Cloudlet:
<https://github.com/SEI-AMS/pycloud>**





Contact Information

Grace A. Lewis

Advanced Mobile Systems (AMS) Initiative

Software Engineering Institute
4500 Fifth Avenue
Pittsburgh, PA 15213-2612
USA

Phone: +1 412-268-5851

Email: glewis@sei.cmu.edu

WWW: <http://www.sei.cmu.edu/staff/glewis/>



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