Towards Elastic Application Model for Augmenting Computing Capabilities of Mobile Platforms

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Outline

- Cloud Computing for CE devices
- Elastic application concept and elasticity patterns
- Cost model
- Reference Implementation and applications
- Experimental Validations

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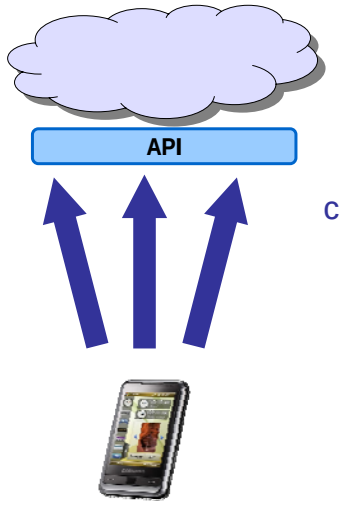
CE + Cloud Computing (1 of 2)

IT View of
Cloud Computing

cloud = web service platform

- Cloud is a platform for ***service delivery***
- Push from services into devices

CE + Cloud Computing (2 of 2)



Proposed CE View of Cloud Computing

cloud = data/core/network center + API

- Cloud is a platform *new applications* that run across the cloud and device ("elastic applications")
- API exposes cloud to device apps
- *Expand the device into the cloud*

Ongoing Approaches for Mobile + Cloud

- CloneCloud (HotCloud'09)
  - Clone of phone image at cloud
- Splitting applications between device and cloud
  - Dynamic partitioning of applications (MCS'10)
  - Dynamic remote method invocation with managed code (Mobisys'10)
- Dynamic Composable Computing (HotMobile'08)
  - Dynamic composition of functions with mobile devices and surrogates.
- Cloudlet (PVC'09)
  - Offloading VM to proximate infrastructure
  - 60-90s on VM synthesis
- HW-supported VM migration (Atom) (MobiCase'09)
  - Focus on mobility of app
- ...

- Elastic Device/Application
  - On application level
  - Dynamic execution configuration
  - More flexible and easy for parallel...

Motivation

CE Devices

Compute – Fixed
Storage – Fixed*
Power – Limited
Bandwidth – Limited
Applications – CONSTRAINED

The Cloud

Compute – ELASTIC
Storage – ELASTIC
Applications – UNCONSTRAINED

The goal of the Elastic Device is to *enable development of cross device/cloud applications*. The advantages are:

- Remove device constraints, create *new classes of powerful applications*
- Help realize a *new business model* for device applications
- Provide developers a *transition path to multi/many core*

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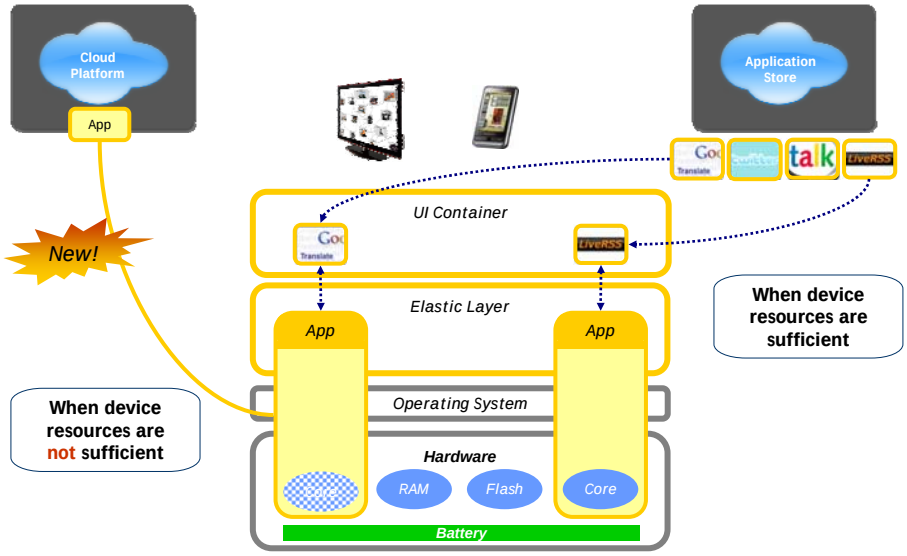
Elastic Device Concept



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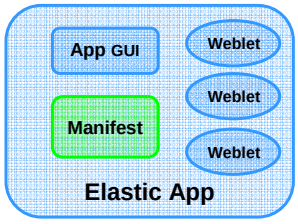
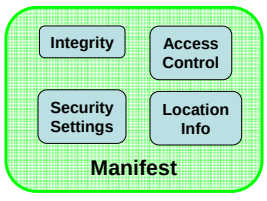
Elastic Applications (EA)

- EA are **cloud aware** applications
- **Weblets**
  - Define discrete application components
  - Communicate using REST interface
  - Run on Device or Cloud
  - Can be replicated to handle loads
- **Application GUI**
  - Launches the program
  - Directs the creation of new weblets
- **Manifest**
  - Meta-data of EA
  - Dynamic configuration info
  - Integrity of weblets
  - Policies for each weblet
    - E.g. JVM, network, access control, location





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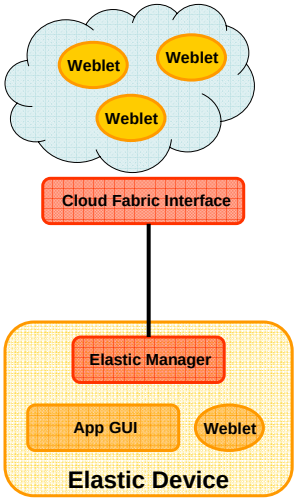
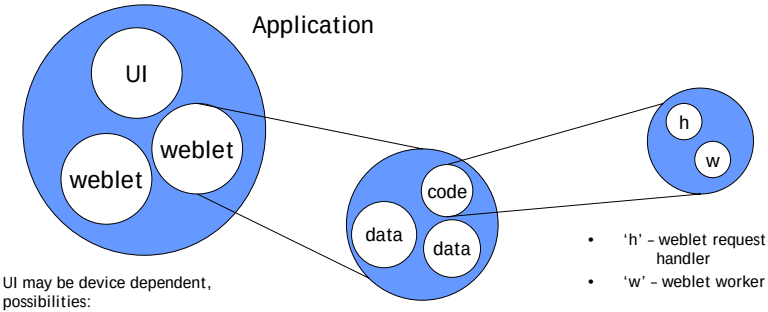
Elastic Devices (ED)

- ED support EAs
  - Enable seamless migration of weblets
  - Manage resources to optimize costs
  - Interface with cloud providers
- **Elastic Manager**
  - Spawns weblets on demand
  - Migrates weblets to / from cloud
  - Senses resource availability
- **Cloud Fabric Interface**
  - Exposes cloud services to devices
  - Controls weblets on behalf of EM
    - Start / Stop / Create / Destroy
  - Can provide PaaS or IaaS model



Application Model



- UI may be device dependent, possibilities:
  - Native code
  - HTML+CSS+JavaScript
  - Flash or Silverlight …
- Weblets are device independent, possibilities:
  - Java bytecode
  - CLR bytecode
  - Python bytecode …

- Autonomous
- Communicate via HTTP
- Long-living requests
- Dedicated (to a client)
- Persistent data
- Migratable
- Synchronizable

- 'h' – weblet request handler
- 'w' – weblet worker

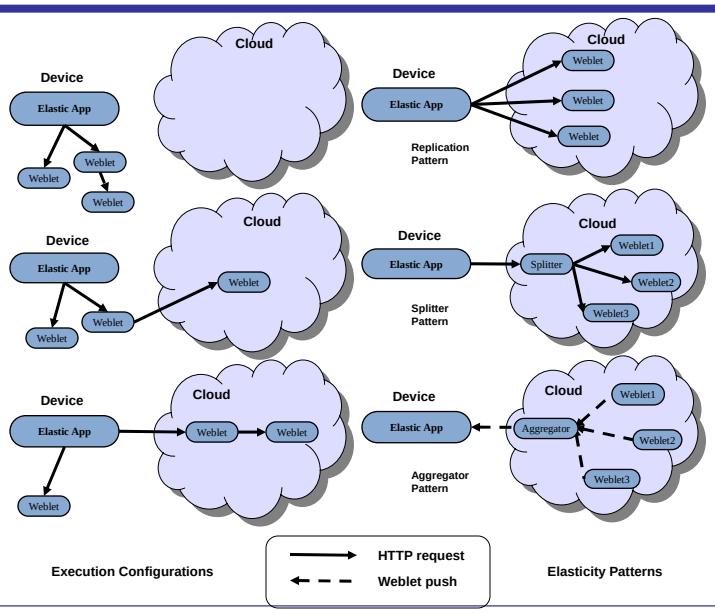
Benefits

- Many-to-one virtualization
  - Seamlessly expands and shrinks of platform capability
- Dynamic user experience
  - User control of expending/shrinking based on factors such as battery consuming, monetary cost, latency/throughput, etc.
- Device flexibility
  - CE device computation and storage capabilities need not be designed to satisfy the most demanding applications.
- Dependability
  - Migrating applications to cloud when device is low in battery/weak signal
- Future proof:
  - Move app from cloud to device, extend app lifetime, reduce development cost

Weblets vs Web Services

Weblet	Web Service
HTTP (REST interface)	HTTP (REST or SOAP interface)
single client	many clients
short-lived & long-lived requests	short-lived requests
dynamic endpoints (may migrate)	fixed endpoints (eg, http://www.google.com)
lifetime is client dependent	lifetime is client independent
runs on servers or client (cloud or device)	runs on servers
push to client	NA / non-standard

Elasticity Patterns



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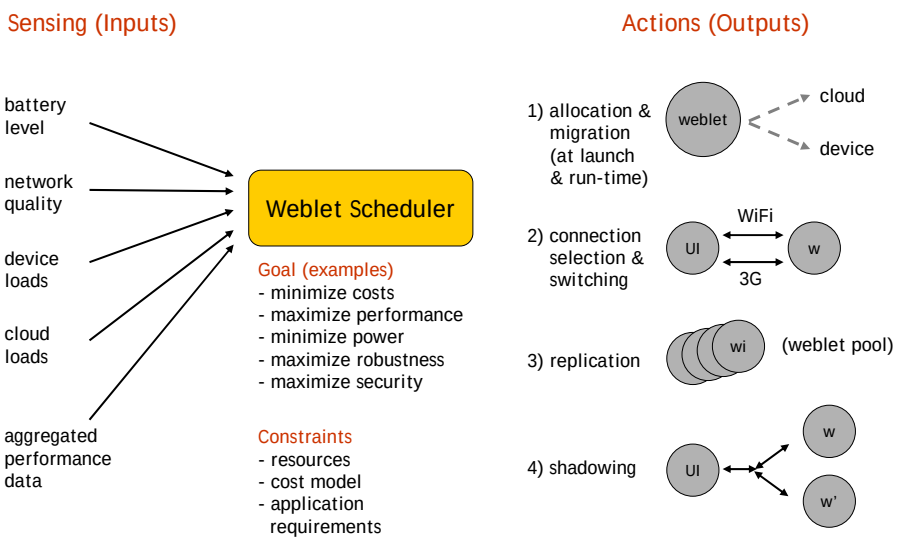
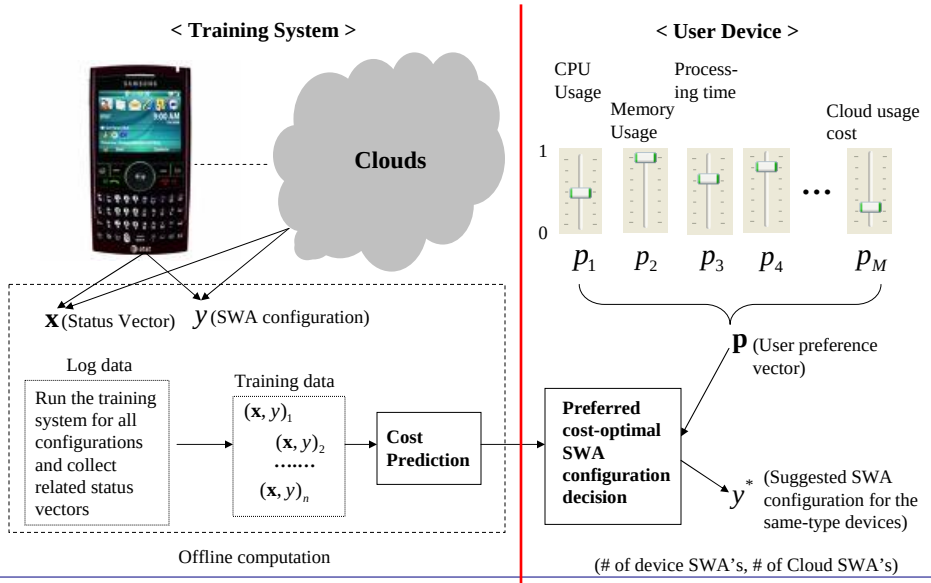
Cost Model



Cost-Optimal Execution Configuration



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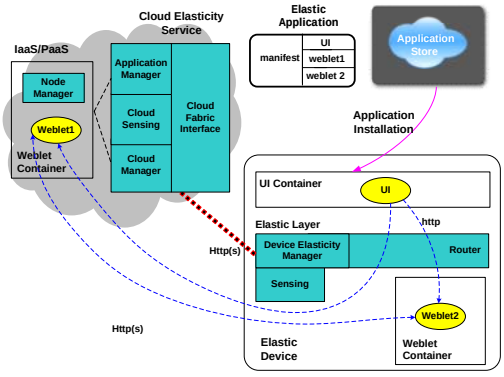
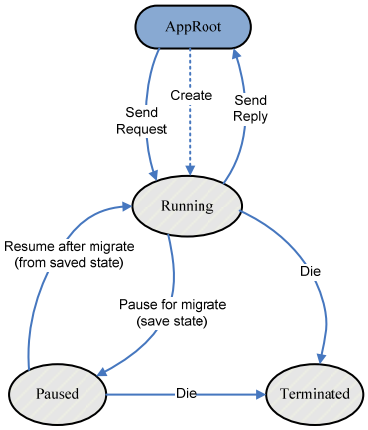
Reference Architecture

- Elastic application package including UI and weblets
- Cloud nodes running on Amazon EC2 instances
- Web service –based CFI
- Application installation on both cloud and device sides



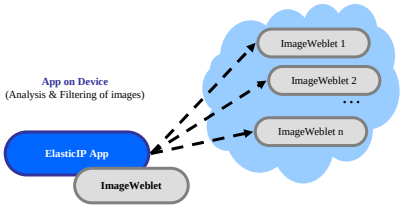
SDK Development

- C# binding only so far
- A weble is an independent functional unit of an application
- A weblet resembles an embedded or dedicated web server
  - presents a web service interface accessed via HTTP
- AppRoot is root UI of an application
- Actions are HTTP requests



Elastic Image Processing

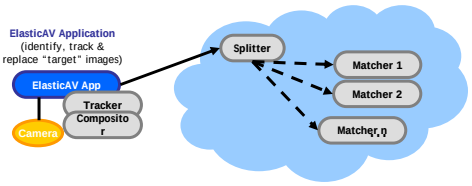
Samsung Q1 | Samsung Omnia | Samsung Galaxy | Monitor



on device: image processing
on cloud: image processing

Elastic Augmented Video

Samsung Q1

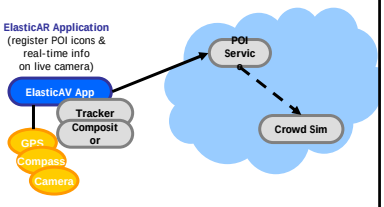


planar object recognition and replacement

on device: feature point extraction from video, tracking, compositing
on cloud: matching live features against library of target images

Elastic Augmented Reality

Samsung
Galaxy



on device: using compass and GPS to align POI markers with live video from camera
on cloud: POI service and crowd simulator (gives # people in proximity to POI's)

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Experimental Validation

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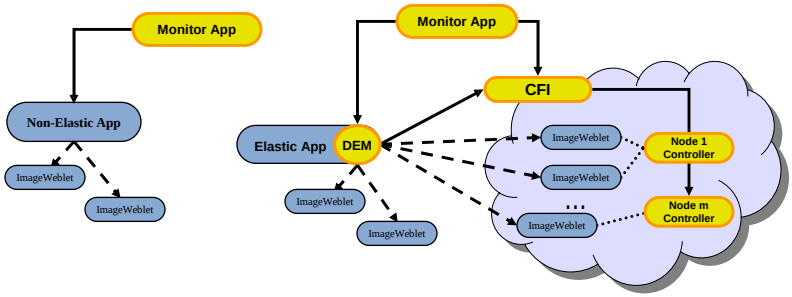
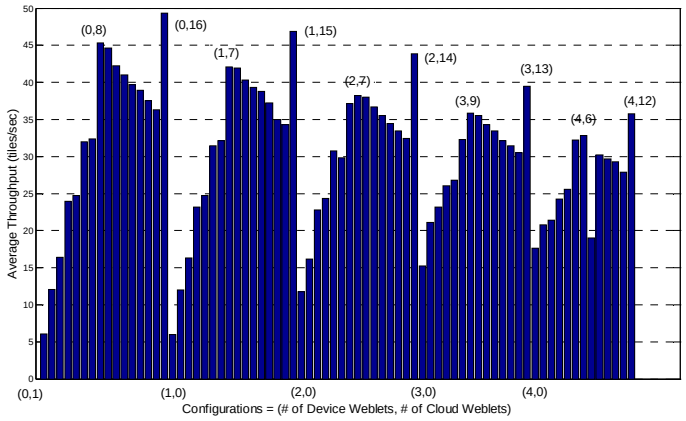
  - Running on device only and on lab cloud cluster
  - LAMP as web service stack on each cloud node
  - Measured upload/download bandwidth, workload, cpu usage, and available memory



Throughput vs. Configurations



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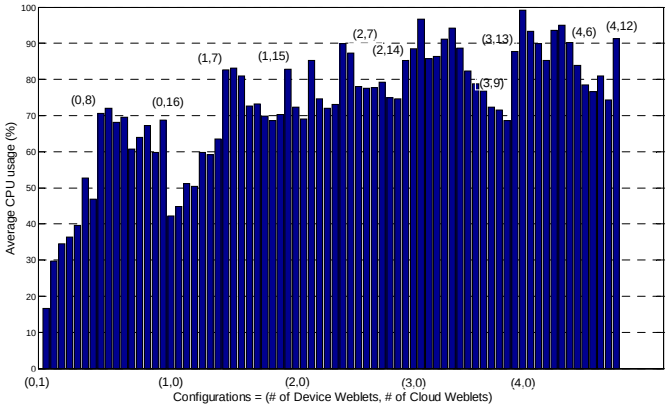
CPU usage rate vs. configurations



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Ongoing and Future Work

- Implementation of more general cost optimization
  - With more sensing data from both device and cloud
  - Cost model as a service
- Migration and replicate of code and data
  - Some synchronizing protocols
  - Allow offline
- Security and privacy
  - Mutual authentication between weblets on device and cloud
  - Authorization delegation to weblets running on public cloud

Q & A