FocusStack: Orchestrating Edge Clouds Using Location-Based Focus of Attention

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What is IaaS?

- Infrastructure-As-A-Service
- Remote datacenter infrastructure: compute, storage, networking and networking services
- In IOT Context
  Treating a cloud of edge devices as our Remote Infrastructure
IOT Devices

• What kind of IOT Devices are we talking about here?

Motivation: Television set-top boxes (Viewership Analytics), Network Gateways, Cars (Weather), and Drones (Remote Sensing: FocusStack to identify a drone close to the target area with sufficient energy left, and deploy the app to it.)

- Limited Compute, Storage, Energy
- Nodes that may be constantly moving
- Intermittent connectivity with variable quality
- Compute-Control Nodes Ratio
• Single Controlling Entity: Tenant and Admins interact through these control nodes

• What type of interactions?
  - deploy new application instances
  - update existing ones
  - configure instances to communicate safely over virtual networks, and
  - provide secure access to storage resources.
FocusStack

• **Problem Domain:**

  1) Inefficient Awareness Messaging

  2) Mixed Initiative Control: Co-management between 1) Controller 2) Admin 3) End-User affects deployment decision making
Solution : FocusStack

- “Focus of attention” of the cloud control plane
- Intelligent geo and context-aware messaging bus
- Location based situational awareness: Scoped based on context that includes the device location, edge device health and capabilities, and user authorization preferences.
- Prevents unnecessary periodic updates to the cloud: Minimizes resource utilization on Edge as well as control node.
- Message Bus can implement security features and authentication.
Implementation Specifics

• Openstack + AT&T Labs Geo Cast System

• Applications deployed using Docker: Each application container can access a full suite of cloud capabilities including the ability to create private and public virtual networks as well as direct access to cloud resources collocated with the controller nodes including cloud storage and VM instances that provide additional compute capabilities.
Application: Shared DashCams

- Providing video from a selection of viewpoints

Use Cases:
1) Avoiding Long Lines at the DMV
2) Fall Colors
3) Drone Event Watching

- Vehicles have a FocusStack device installed and are connected to the Internet using cellular LTE data service (Vehicles = Drones/Cars)

- Why do we need Situational Awareness?:
  Assumptions: Geographic selection; Sensor selection; computational, communications, energy, and opt-in state of participating vehicles
Figure 1. FocusStack Architecture
• Hybrid Cloud:
  Edge devices running lightweight Linux containers (based on Docker)
  Cloud-based compute nodes that can run virtual machines (VMs) like an IaaS cloud.

• OpenStack extension (OSE) that allows deployment, execution and management of containers on small edge computing devices with limited networking capabilities.

• Upon Cloud Operation invocation: the LSA subsystem based on a Geocast Georouter is first used to scope this request.

• The resulting “focus of attention” list of edge nodes is then used to seed the appropriate OpenStack operation with the help of a component called the conductor.
LSA

- **GA**: Geographic Addressing
  API analogous to (and in parallel with) the IP stack

- **ALGS**: UDP Packets, bidirectional asynchronous communication, timeout = 1-3 minutes [edge nodes have to keep refreshing], also supports ad-hoc Wifi
FCOP - Field Common Operating Picture

• A set of devices monitoring each other

• In gist: If, for last P seconds, a device hasn’t had any update from another, it sends a Query and a response has to be sent back, and recorded on the side of sender.

• For DashCam P=10

• Avoids redundant querying by 1) Only querying when no updates found 2) Storing a picture record

• It can use 2 approaches: 1) Unicast(UDP) 2) Flooding(Ad hoc Wifi) from peer to peer.
Figure 5. GCLib framework software architecture.
GCHub components

- Pub: Publish/Subscribe system for sensor data [used by apps on the edge device]: They send tag based information

- GCHub: Like a Post Office; You could send/subscribe for certain messages; Formats information into geocast packets

- Responder component registers interest in incoming query messages
SAMonitor

• Creates the **Operating picture** of the area of interest from the query responses. This is a continually updated **data set** recording the set of devices reporting from the area, the information received from each device, and the age of the information.

• In order to remove devices from the Focus, simple deactivate SAMonitor for the device and stop query/response.
So how does all of this work together?

• An application needing to perform a task within a region sets up an SAMonitor for the region with a query such as:
  [Q.AND][App.Dashcam][LLA][Energy][CompState]

• Q.And -> Device Spec must contain all tags

• App.Dashcam -> Device must opt for DashCam Service

• LLA, Energy, CompState -> Monitored parameters
• The Responder from GCHub will send a response back to the SAMonitor, which in turn will create an Operating Picture, which is handed to the OSE.

• If the OSE finds that deployment is feasible, it invokes Nova to do ahead with the management tasks.

• These management tasks are done within Secure VPN Channels
OSE Subsystem

- **Edge Compute Nodes:**
  Nodes run a custom version of Nova Compute that interacts with a local Docker instance to launch and manage containers.

- **Conductor:** Decision make in OSE

- **Messaging:** AMQP by RabbitMQ. Multicasted to all the compute nodes [Topic = compute]
Evaluation: DashCam

• Implementation Specifics: The edge compute device we chose is the Raspberry Pi 2 Model B running Ubuntu Mate 15.10. We augmented the Raspberry Pis with a 5MP, 1080p camera, GPS receiver and LTE dongle. The user interface consists of an Android application running on a tablet mounted in the vehicle.

• Node Mobility & Networking:
  Problem of changing IP Addresses
  Solution: 1) Geographical Addressing; 2) Video streaming system in Dashcam uses TCP so they have used private IP Addresses from DHCPs

• Drone extension: Has an added tag of “Energy"
Evaluation: Network & Processing Cost

- If in the future all cars on U.S. roads become Dashcam devices: 5100 accidents per day in the U.S. as of 2005; assume that Dashcam users are interested in all and only these accidents.

- Next assume the area of interest for an accident covers 1000 cars and the time of interest lasts 2 hours per accident.

- Using OpenStack with full-time active monitoring would cost 431 times as many bytes transmitted over LTE as our prototype FocusStack.

- Awareness traffic is proportional only to the number of applications and the sizes of focus regions, independent of how many FocusStack control planes may be running.
Accepted Limitations

- Edge devices cannot be trusted
- Presence of Third Party: Three authentications that must be strong and enforced: user to application, application to cloud, and user to cloud.
- Issues in Mixed Initiative Control: Decision to usurp computations
Disadvantages

- Maintaining Real-Time FCOP is a challenge
- In GCHub: Functions of sensor component is not very clear. Is it just API for sensors?
- Does not clearly demonstrate Mixed Initiative
- No mention of formula for location aware situational decisions - working of the Conductor
Disadvantages

• Changing IP Addresses due to mobility of edge devices

• Alice can then tap on Bob’s node icon to have FocusStack deploy a Shared Dashcam container to Bob’s car and send her the video feed, providing her the ability to assess the potential wait time - unjustified use case

• Confusion on Implementation:
  At one point in paper, it’s mentioned: “One of our goals is to build a platform that handles the underlying details of discovering an appropriate collection of edge devices” Discovering or the user has to sign up?
References

• Mixed Initiative:

• FCOP: