ICON: Intelligent Container Overlays

A. Zavodovski, N. Mohan, S. Bayhan, W. Wong and J. Kangasharju

HotNets 2018,
November 15-16, 2018
Motivation: Edge Computing
Motivation: Edge Computing

Latency-critical services are predeployed to edge facilities
Motivation: Edge Computing

Latency-critical services are predeployed to edge facilities
Motivation: Edge Computing

Latency-critical services are predeployed to edge facilities.
Motivation: Edge Computing

Latency-critical services are predeployed to edge facilities
Motivation: Edge Computing

Latency-critical services are predeployed to edge facilities.

Using app without edge is slow, users are not quite content.
Motivation: Edge Computing

Latency-critical services are predeployed to edge facilities.

Using app without edge is slow, users are not quite content.

How to discover local edge servers? Are there any?
CDN for Services?
CDN for Services?

NO!
CDN for Services?

NO!

Open Standards
CDN for Services?

NO!

Open Standards
Decentralized Solution
CDN for Services?

NO!

Open Standards

Decentralized Solution

Something like the Internet!
Motivation

• Growing demand for edge computing, making edge pervasive
• Applications should unfold towards the edge autonomously
• Managing applications by setting only high level objectives
• Autonomous adaptation to the changing environment
Motivation

- Growing demand for edge computing, making edge pervasive
- Applications should unfold towards the edge autonomously
- Managing applications by setting only high level objectives
- Autonomous adaptation to the changing environment
- Towards common standards of self-organized service provisioning on global scale
Motivation

• Growing demand for edge computing, making edge pervasive
• Applications should unfold towards the edge autonomously
• Managing applications by setting only high level objectives
• Autonomous adaptation to the changing environment
• Towards common standards of self-organized service provisioning on global scale
• Not only about the edge!
ICON: Intelligent Container

• Virtualized entity containing a service
  • Built on top of Docker container, VM, unikernel, etc.
  • Oriented towards microservices architecture (application is a collection of loosely coupled services)
ICON: Intelligent Container

• Virtualized entity containing a service
  • Built on top of Docker container, VM, unikernel, etc.
  • Oriented towards microservices architecture (application is a collection of loosely coupled services)

• Capable of observing the environment
  • Monitors where incoming flows come from
  • Discovers potential deployment locations
ICON: Intelligent Container

• Virtualized entity containing a service
  • Built on top of Docker container, VM, unikernel, etc.
  • Oriented towards microservices architecture (application is a collection of loosely coupled services)

• Capable of observing the environment
  • Monitors where incoming flows come from
  • Discovers potential deployment locations

• Capable of taking decisions and acting autonomously
  • Migrates or replicates closer to end-users to satisfy, e.g., latency objectives
  • Terminates if utility falls below predefined threshold
Operation of ICON

- Initially, ICON is in the cloud
  - One or multiple origination points
Operation of ICON

- Initially, ICON is in the cloud
  - One or multiple origination points
- ICON monitors incoming flows
  - Where requests are coming from?
Operation of ICON

- Initially, ICON is in the cloud
  - One or multiple origination points
- ICON monitors incoming flows
  - Where requests are coming from?
- **ICON discovers deployment locations**
  - In the domain of end-users or on a path to it
Operation of ICON

• Initially, ICON is in the cloud
  • One or multiple origination points

• ICON monitors incoming flows
  • Where requests are coming from?

• ICON discovers deployment locations
  • In the domain of end-users or on a path to it

• ICON can take autonomous decisions
  • Deploy replica of itself
Operation of ICON

• Initially, ICON is in the cloud
  • One or multiple origination points
• ICON monitors incoming flows
  • Where requests are coming from?
• ICON discovers deployment locations
  • In the domain of end-users or on a path to it
• ICON can take autonomous decisions
  • Deploy replica of itself
The Operation of ICON

• Initially, ICON is in the cloud
  • One or multiple origination points
• ICON monitors incoming flows
  • Where requests are coming from?
• ICON discovers deployment locations
  • In the domain of end-users or on a path to it
• ICON can take autonomous decisions
  • Deploy replica of itself
  • **Migrate closer to the end-users**
Overlay of ICONs

Origin

Tokyo
Overlay of ICONs

• Tree is formed organically as ICONs deploy replicas of themselves
  • Efficient for information propagation
• Coordination
• Control
• Other topologies are possible (e.g., swarm)
Independent Edge Providers (IEPs)

• Facility where ICON can deploy itself
• Can be:
  • Facility operated by a cloud provider (e.g., Cloudfront, Azure Stack)
  • Telco edge server (MEC)
  • Crowdsourced: iExec, Golem, etc.?
• Runs **container yard** application
  • Built on top of e.g., Kubernetes, Mesos or Docker Swarm
  • ICON negotiates with the yard on deployment timeslot, hardware resources, price, etc.
• Contractual agreements and transactions
  • Smart contracts are possible option
Independent Edge Providers (IEPs)

• Facility where ICON can deploy itself
• Can be:
  • Facility operated by a cloud provider (e.g., Cloudfront, Azure Stack)
  • Telco edge server (MEC)
  • Crowdsourced: iExec, Golem, etc.?
• Runs *container yard* application
  • Built on top of e.g., Kubernetes, Mesos or Docker Swarm
  • ICON negotiates with the yard on deployment timeslot, hardware resources, price, etc.
• Contractual agreements and transactions
  • Smart contracts are possible option

Anyone can establish an IEP
Discovery of IEPs

• Assumption: IEPs add edge SRV records to authoritative DNS servers of their domains
Discovery of IEPs

• Assumption: IEPs add **edge** SRV records to authoritative DNS servers of their domains

• **Perform tomography**
  • **Traceroute** to end-users
Discovery of IEPs

• Assumption: IEPs add **edge** SRV records to authoritative DNS servers of their domains

• Perform tomography
  • **Traceroute** to end-users

• **Identify on-path domains**
Discovery of IEPs

• Assumption: IEPs add edge SRV records to authoritative DNS servers of their domains

• Perform tomography
  • Traceroute to end-users

• Identify on-path domains

• Perform SRV query
Discovery of IEPs

- Assumption: IEPs add **edge** SRV records to authoritative DNS servers of their domains
- Perform tomography
  - **Traceroute** to end-users
- Identify on-path domains
- **Perform SRV query**
Discovery of IEPs

• Assumption: IEPs add **edge** SRV records to authoritative DNS servers of their domains

• Perform tomography
  • **Traceroute** to end-users

• Identify on-path domains

• **Perform SRV query**
Intelligence of ICONs

• Easy version: Governed by utility function
  • Weights are “control knobs”, e.g., budget vs. latency
  • Application owner can also “hotswap” the entire utility function

• Thresholds: When expected utility of an action exceeds certain boundary value:
  • Replicate
  • Migrate
  • Terminate

• More complex version: Overlay forms a picture of the world and adapts the network as a whole
Open Questions
Open Questions

• Intelligence
  • What kind of intelligence do ICONs need?
Open Questions

• Intelligence
  • What kind of intelligence do ICONs need?

• Discovery of the closest ICON
  • How new clients will discover the ICON which is closest to them?
Open Questions

• Intelligence
  • What kind of intelligence do ICONs need?

• Discovery of the closest ICON
  • How new clients will discover the ICON which is closest to them?

• Security
  • Trusted execution environments?
Open Questions

• Intelligence
  • What kind of intelligence do ICONs need?

• Discovery of the closest ICON
  • How new clients will discover the ICON which is closest to them?

• Security
  • Trusted execution environments?

• Contractual agreement between ICON and independent edge providers
  • Are smart contracts the best option?
Future Work
Future Work

- Implementing *container yard* for hosting ICONs
Future Work

• Implementing *container yard* for hosting ICONs
• Negotiation protocol
  • Like all routers support IP, facilities providing capacity to run services should support some common protocol to negotiate on new service deployment
Future Work

• Implementing *container yard* for hosting ICONs
• Negotiation protocol
  • Like all routers support IP, facilities providing capacity to run services should support some common protocol to negotiate on new service deployment
• Sophisticated intelligence
  • Proactively predicting where from most of the requests will come
Future Work

• Implementing *container yard* for hosting ICONs
• Negotiation protocol
  • Like all routers support IP, facilities providing capacity to run services should support some common protocol to negotiate on new service deployment
• Sophisticated intelligence
  • Proactively predicting where from most of the requests will come
• Game theoretic analysis
  • What if two (or more) competing applications are deployed using ICONs?
Future Work

• Implementing *container yard* for hosting ICONs

• Negotiation protocol
  • Like all routers support IP, facilities providing capacity to run services should support some common protocol to negotiate on new service deployment

• Sophisticated intelligence
  • Proactively predicting where from most of the requests will come

• Game theoretic analysis
  • What if two (or more) competing applications are deployed using ICONs?

• Specialized ICONs forming chains of services, and multitier apps
  • Not limited to edge, e.g., a database may also be packed as ICON
  • How to coordinate?
Summary: Why ICONs?
Summary: Why ICONs?

• IEPs to tackle growing demand for edge computing
  • Less cloud monopoly
Summary: Why ICONs?

• IEPs to tackle growing demand for edge computing
  • Less cloud monopoly
• Open infrastructure standards to enable ad hoc deployment of services on global scale
Summary: Why ICONs?

• IEPs to tackle growing demand for edge computing
  • Less cloud monopoly
• Open infrastructure standards to enable ad hoc deployment of services on global scale
• Reducing administrative overhead: applications move across the network themselves following high level objectives
Summary: Why ICONs?

• IEPs to tackle growing demand for edge computing
  • Less cloud monopoly
• Open infrastructure standards to enable ad hoc deployment of services on global scale
• Reducing administrative overhead: applications move across the network themselves following high level objectives
• Taking advantage of autonomous local decision-making leads to faster adaptation to changing environment
Summary: Why ICONs?

• IEPs to tackle growing demand for edge computing
  • Less cloud monopoly
• Open infrastructure standards to enable ad hoc deployment of services on global scale
• Reducing administrative overhead: applications move across the network themselves following high level objectives
• Taking advantage of autonomous local decision-making leads to faster adaptation to changing environment

Thank you!
Summary: Why ICONs?

• IEPs to tackle growing demand for edge computing
  • Less cloud monopoly
• Open infrastructure standards to enable ad hoc deployment of services on global scale
• Reducing administrative overhead: applications move across the network themselves following high level objectives
• Taking advantage of autonomous local decision-making leads to faster adaptation to changing environment

Thank you!  aleksandr.zavodovski@helsinki.fi