The Impact of Mobile Multimedia Applications on Data Center Consolidation

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Consolidation is the key to Cloud computing

- Cloud computing achieves economies of scale by consolidating resources
  - It lower the marginal cost of operation and management
  - Amazons EC2 spans the entire planet with 7 data centers
- Large separation between a mobile device and its cloud
  - High latency in end-to-end communication
  - Challenges for latency sensitive applications

From http://gcn.com/articles/2012/10/26/agency-data-centers-idc-report.aspx

Emerging Mobile Applications

A new class of applications using video/voice in mobile context

- Apple's Siri, Augmented reality applications
- Many of these are interactive as well as resource-intensive
  - Beyond the processing and storage limits of mobile device
  - **Use Cloud to offload execution**
- Wearable Devices like Google Glass will push this trend more

From http://www.google.com/glass/start/ and http://www.flickr.com/photos/x1brett/4600461689/

Questions

1. Do we really need to offload?
2. What's the effect of Cloud location?
3. In situation where public Clouds are inadequate, what would be an alternative Cloud architecture?

Applications Studied

Applications

- Resource intensive and latency sensitive applications

Application	Input	Output	Execution Environment
Face Recognition	Image	Name and position of a detected face	OpenCV on Windows
Speech Recognition	Audio	Words in plain text format	Java on Linux
Object Recognition	Image	Names and positions of found objects	C++ on Linux
Augmented Reality	Image	Name (information) of recognized landmark	OpenCV & Intel IPP on Windows
Fluid Simulation	Acc data	Location and pressure of simulated particles	C++ on Linux

1. Do we need to offload?

Extremes of resource demands

- It may appear that today's smartphone are already powerful enough
  - Built-in support for face detection in Android SDK

- But, computation varies dramatically depend on operational conditions
  - Face recognition
  1. Increasing number of possible faces,
  2. Reducing the constraints on the observation conditions

1. Do we need to offload?

High variability of execution time

1. *SPEECH recognition*

- Execution time increases with the number of recognized words

	no words recognized	1-5 words recognized	6-22 words recognized
Measured average time	0.057 s	1.04 s	4.08 s

2. *FACE recognition*

- Execution time varies depends on the contents of images

Image with single big face	Image with no face
0.30 s	3.92 s

* Tested with a netbook as a mobile device

1. Do we need to offload?

Improvement from Cloud offloading

- Though variability still exists, the absolute response times are improved

	No Cloud		With Cloud	
	median	99%	median	99%
SPEECH (500 requests)	1.22 s	6.69 s	0.23 s	1.25 s
FACE (300 requests)	0.42 s	4.12 s	0.16 s	1.47 s

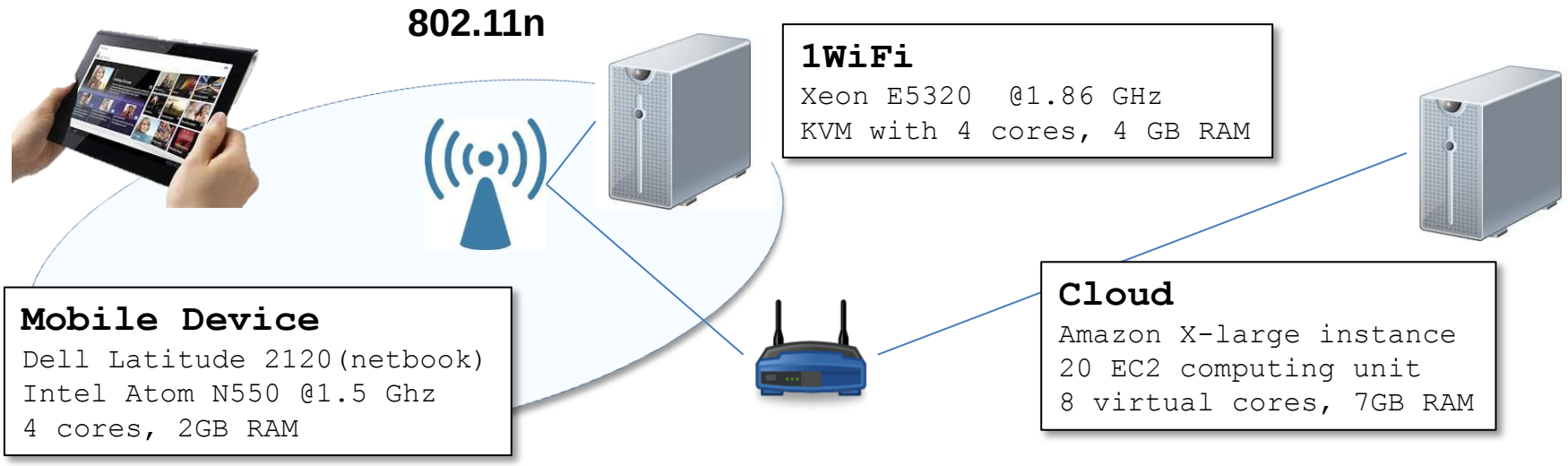
* We used Amazon EC2 for *SPEECH* and private Cloud for *FACE*.

** We used netbook as a mobile device.

2. Effects of Cloud location

Experiment setup

- Mobile (No offloading) : Local execution within mobile device
- Cloud : Offload to Cloud (Amazon EC2)
  - 4 locations: US-East, US-West, EU, Asia
- 1WiFi (One hop) : Offload to nearby compute resource



- Fast mobile/Cloud and a slow Cloudlet configuration
- 1 EC2 Compute Unit ≈ 1.0-1.2 GHz 2007 Xeon processor

2. Effects of Cloud location

Network measurement

- **Average RTT from 260 global vantage points to an "optimal" Amazon EC2 instance is 73.68 ms [1]**
- [CMU – Amazon East] has amazingly good connection, but becomes similar with Amazon West case if it is measured off-campus

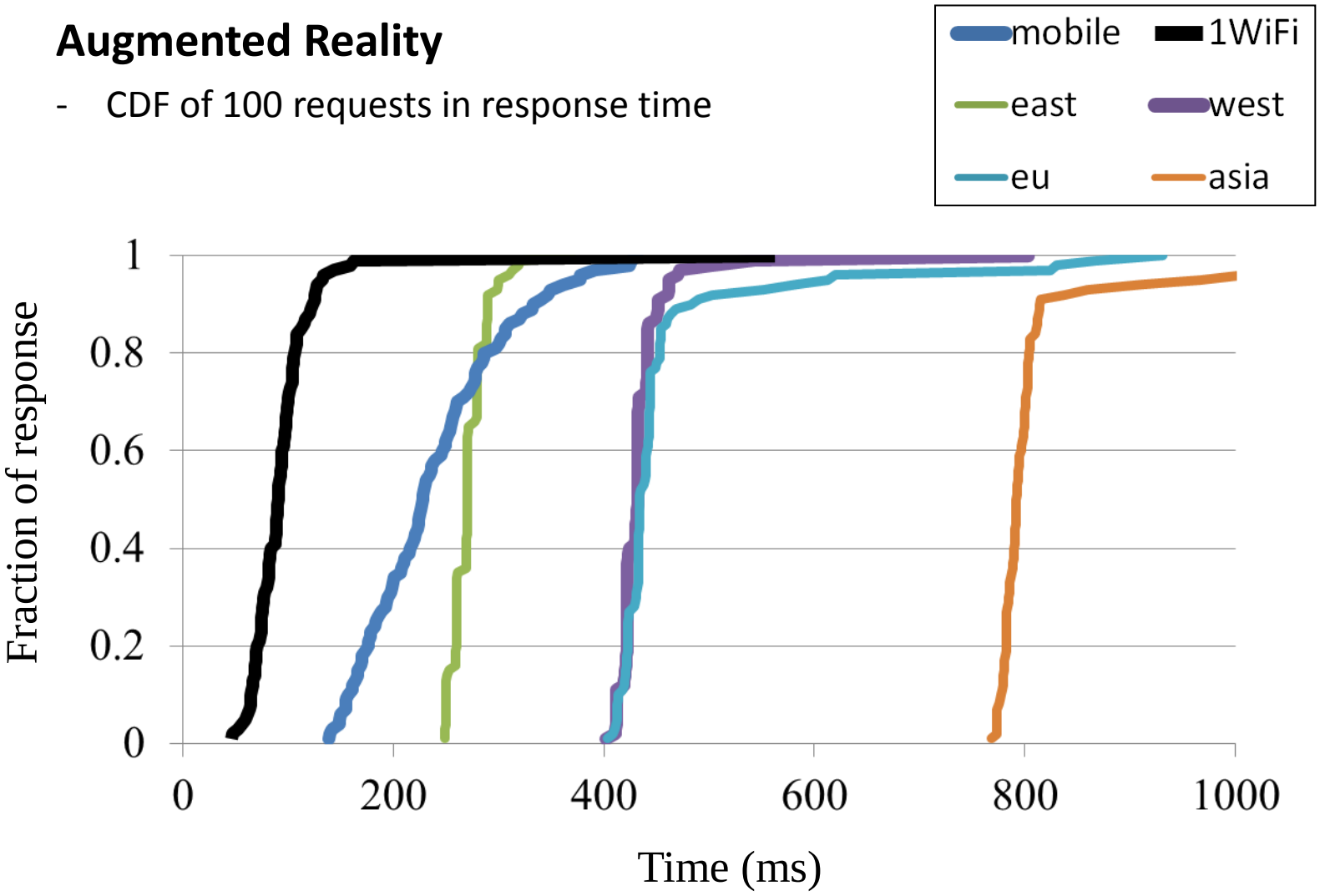
EC2	Throughput (Mbps)		Latency (RTT, ms)
	To	From	median
East	28	34	9.2
West	**12**	**14**	**92**
EU	3.6	0.9	99
Asia	10	0.5	265

< From mobile to different Cloud via 802.11n >

Impact on response time

Augmented Reality

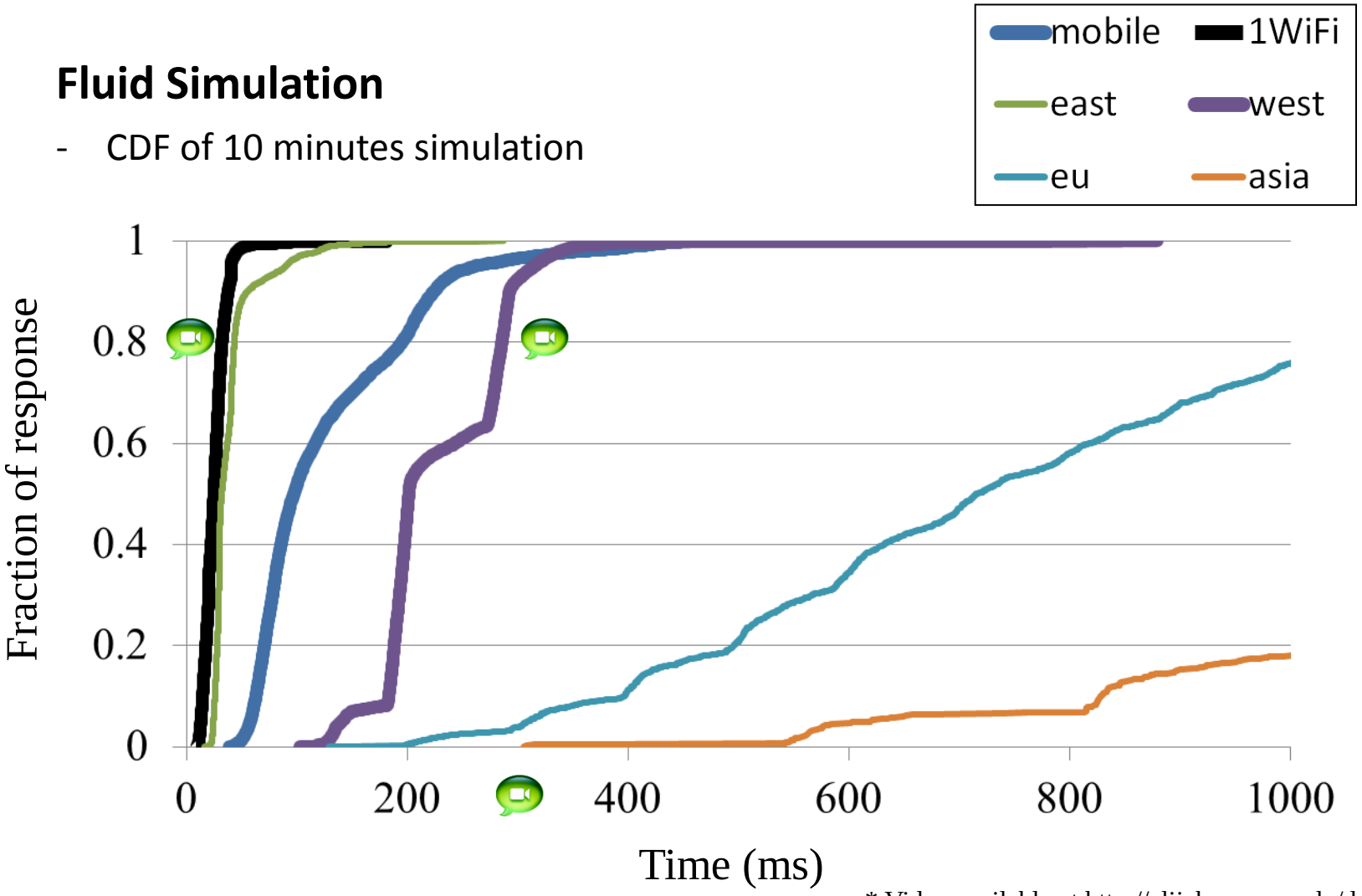
- CDF of 100 requests in response time



Impact on response time

Fluid Simulation

- CDF of 10 minutes simulation

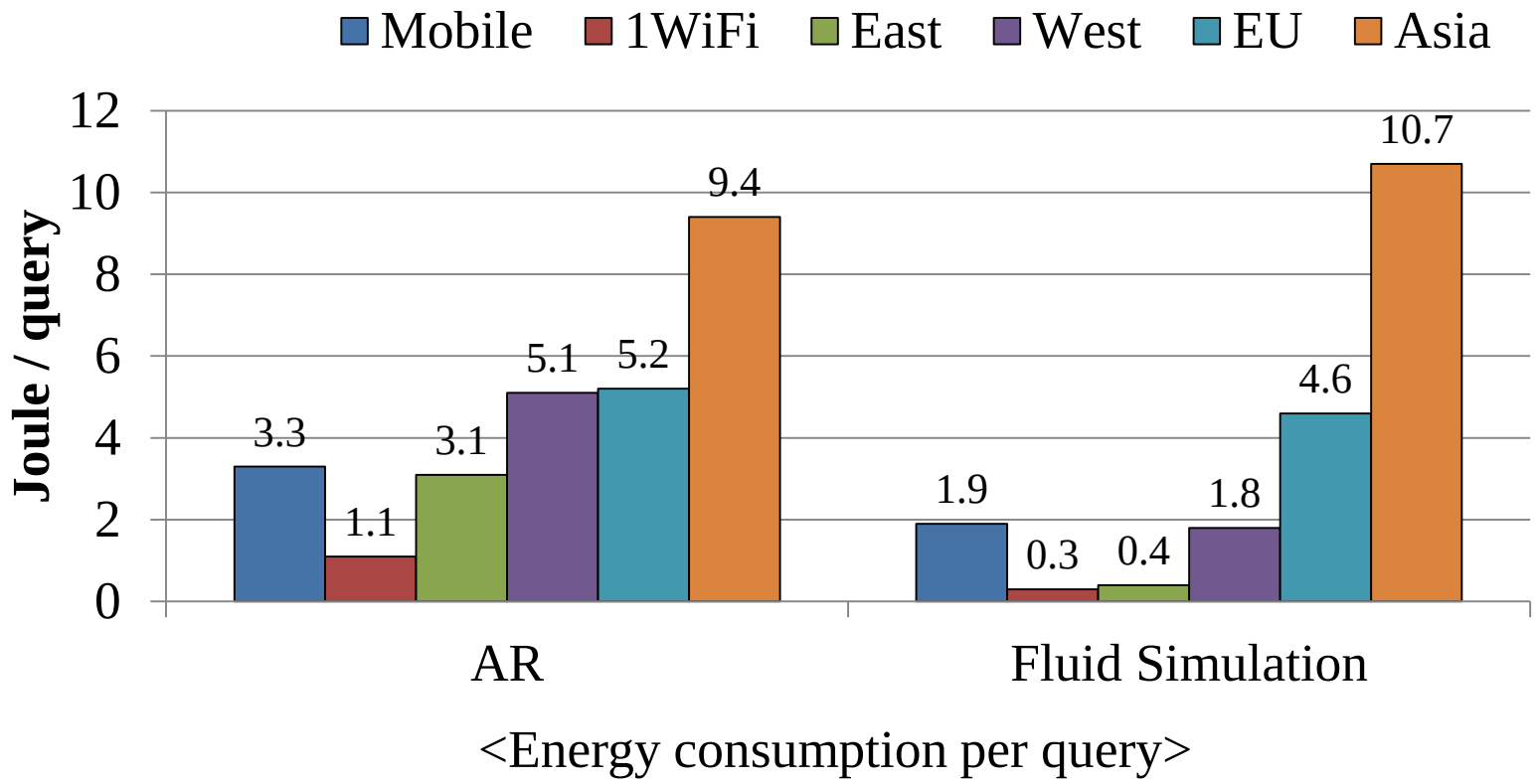


* Video available at http://elijah.cs.cmu.edu/demo.html

Impact on Energy Usage

Energy consumption on mobile device

- Measured while the response time experiment



<Energy consumption per query>

* netbook's baseline idle power dissipation is 10W

Effects of Cloud location

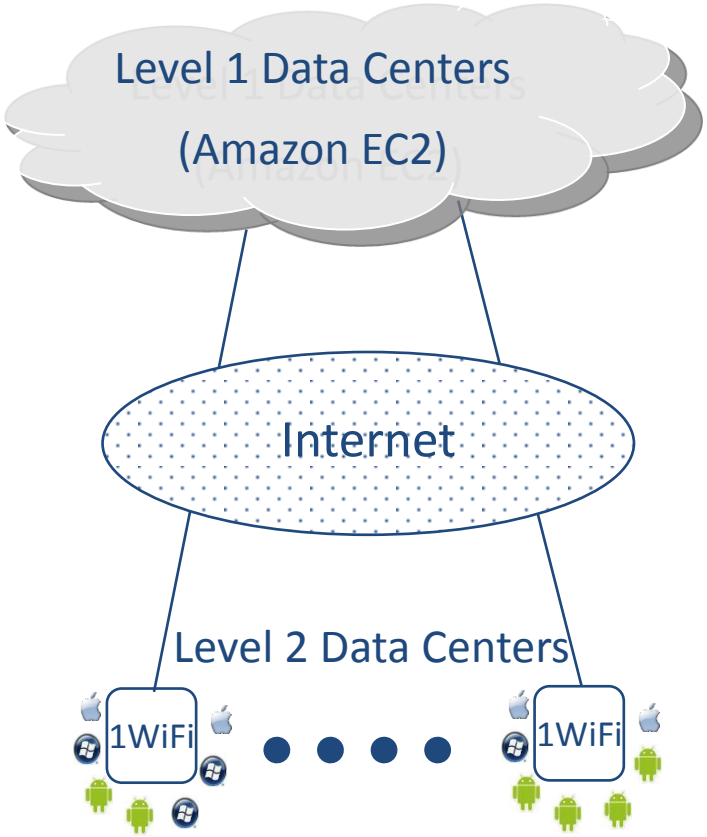
- Proximity to the data center is essential
  - Response time & Energy consumption
- 1WiFi Cloud
  - The best attainable proximity
  - The emerging of such applications can be accelerated by deploying infrastructure that assures continuous proximity to the cloud
- Contradictory requirements
  - **1WiFi is valuable** for mobile computing
  - However, it needs **many data centers at the edges the Internet**

→ How can we reconcile this conflict?

3. What's an alternative Cloud architecture?

Hierarchical organization of data center

- Level 1
  - Today's unmodified Cloud
- Level 2
  - ***Stateless*** data centers at the edge
  - Appliance-like deployment model
  1. Only soft state
     - Cached virtual machine images
     - Cached files from DFS
  2. No hard state keeps management overhead low.



* soft state is state which can be regenerated or replaced

3. Alternative Cloud Architecture

Physical realization

- Hardware technology is already out today
- Repurpose as Level 2 data center by removing hard state and adding self-provisioning

Myoonet's Outdoor micro data center [2]

AOL's micro data center [3]

3. Alternative Cloud Architecture

Operating Environment

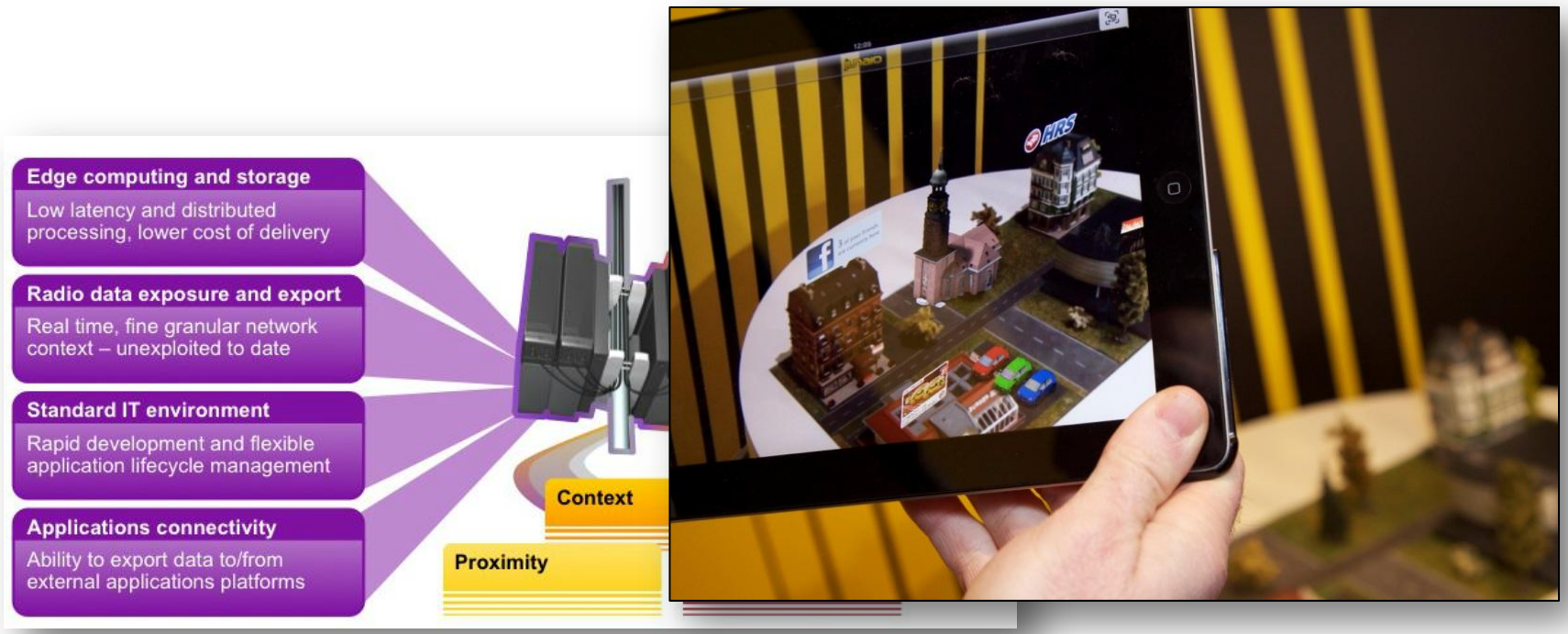
- Commonalities in the requirement between Levels 1 and 2
  1. Strong **isolation** between untrusted user-level computations
  2. Mechanisms for authentications, access control and metering
  3. **Dynamic resource** allocation
  4. The ability to **support a wide range** of user-level computations

  → **Virtual machine** as Cloud of today like EC2

Industrial efforts for 1WiFi Cloud

Nokia Siemens Networks and IBM

- Announced Liquid Applications at MWC 2013
- Deploys the cloud into the (cellular) base station
  - *"Improved latency can enable high-value vertical solutions"..*



Discussion & Future Work

Rapid Provisioning

- Provisioning delay directly impact usability*

Discovery

- How to dynamically find the right Level 2 data center?

Data placement

- Appropriate data placement is important for many “Cloud” applications
- Two extreme ends
  1. Application with relatively small data set for its operation
  2. A very large data set accessed in an unpredictable manner
- **Most applications likely fall between the two ends**
  - Map Data: physical location is highly correlated with accessed data map
  - Automatic caching of distributed file system exploiting locality information

*Kiryong Ha, Padmanabhan Pillai, Wolfgang Richter, Yoshihisa Abe, Mahadev Satyanarayanan, "Just-in-Time Provisioning for Cyber Foraging", In MobiSys 2013 (to appear)

Conclusion

1. Do we really need to offload?

   Cloud offload is here to stay

2. What's the effect of Cloud location?

   Emerging mobile applications endanger cloud consolidation

3. In situation where public Clouds are inadequate,
   what would be an alternative Cloud architecture?

   Hierarchical solution is desirable and feasible

Reference

This work has been accepted from IC2E conference and you can fond the details at http://krha.kr/data/publications/ic2e2013.pdf

Reference

1) A. Li, X. Yang, S. Kandula, and M. Zhang, “Cloudcmp: comparing public cloud providers,” in Proceedings of the 10th annual conference on Internet measurement. ACM, 2010, pp. 1–14.
2) Myoonet, “Unique Scalable Data Centers,” December 2011, http://www.myoonet.com/unique.html.
3) R. Miller, “AOL Brings Micro Data Center Indoors, Adds Wheels,” http://www.datacenterknowledge.com/archives/2012/08/13/aol-brings-micro-data-center-indoors-adds-wheels , August 2012.
4) Kiryong Ha, Padmanabhan Pillai, Wolfgang Richter, Yoshihisa Abe, Mahadev Satyanarayanan, "Just-in-Time Provisioning for Cyber Foraging", In MobiSys 2013 (to appear)