HOT Topics in Computer Science (HOT-T-CS)

Mobile Cloud Computing
Applications

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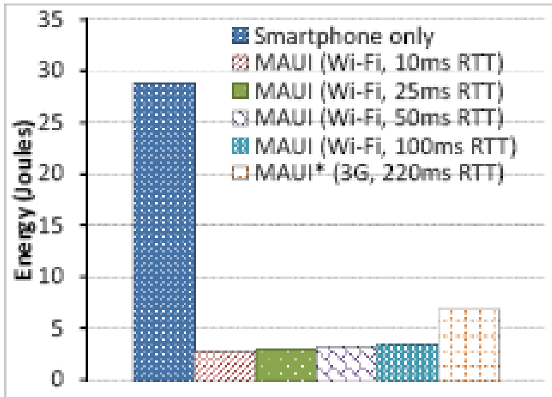
Types of Applications

- Computation Intensive
  - Speech Translation, Computer Vision
- Streaming apps (or data parallel applications)
  - Continuous Sensing and Processing
    - Augmented reality on video streams
- Communication Intensive
  - Social network apps, like Twitter
  - Apps with high push notifications
- Gaming Apps

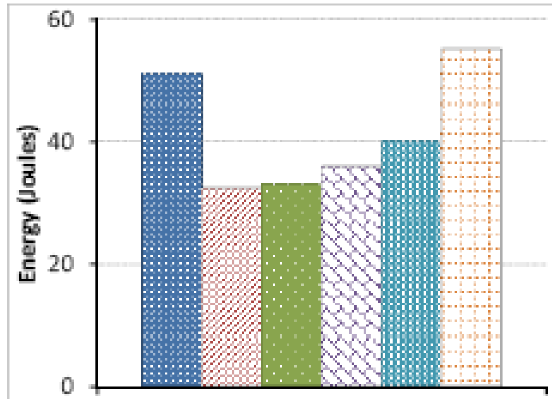
What did MAUI show ?

- MAUI system was evaluated using
  - Face recognition application → computation intensive
  - Video Game → latency sensitive
  - Chess game → computation + latency
- Speech translation → demonstrated how to overcome resource limits on smartphone

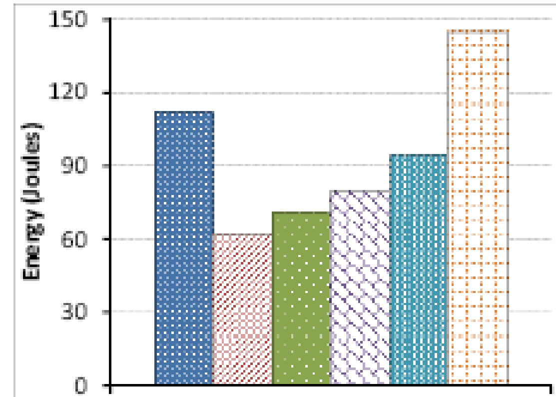
[1] MAUI Results: Energy Savings



ONE RUN FACE RECOGNITION



400 FRAMES of VIDEO GAME



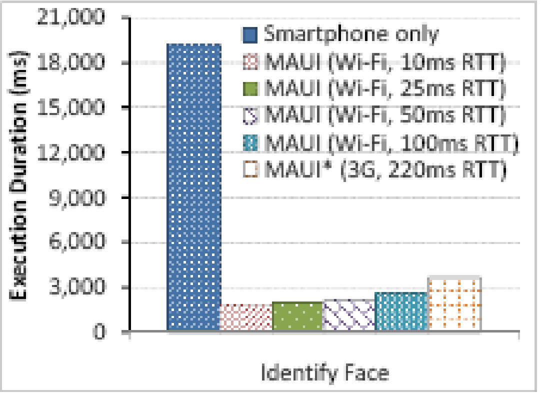
30 MOVE CHESS GAME

- One order of magnitude improvement
- On 3G, the energy consumption is higher than that over WiFi

- Improvement over WiFi
- On 3G, there is no energy gain

- The gains are diminishing
- On 3G, there is no energy gain

[2] MAUI Results: Execution Time Savings



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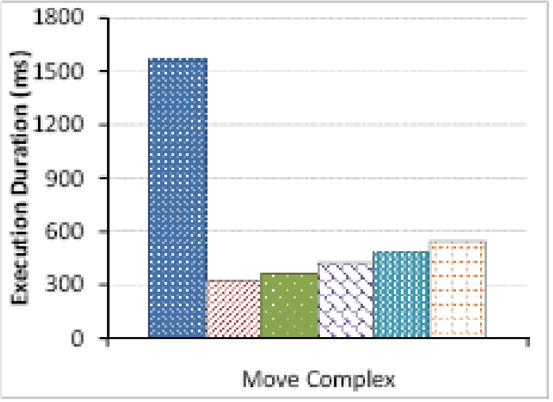

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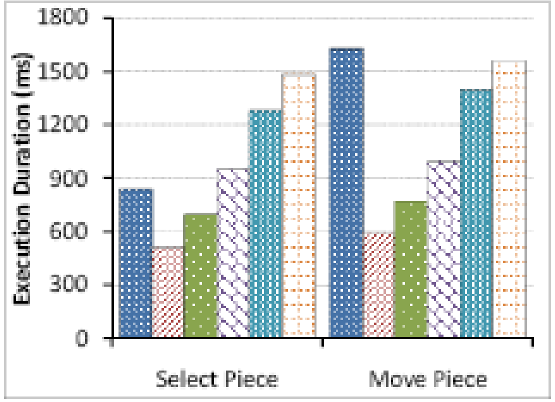


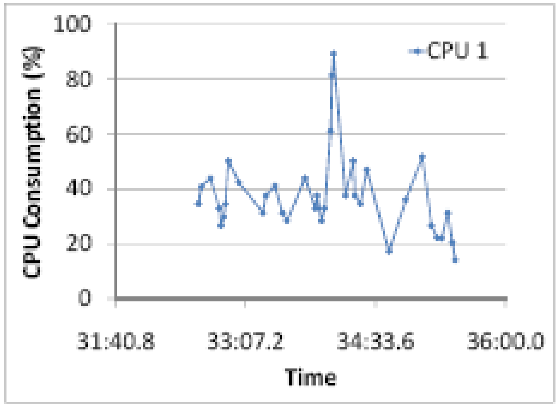
30 MOVE CHESS GAME

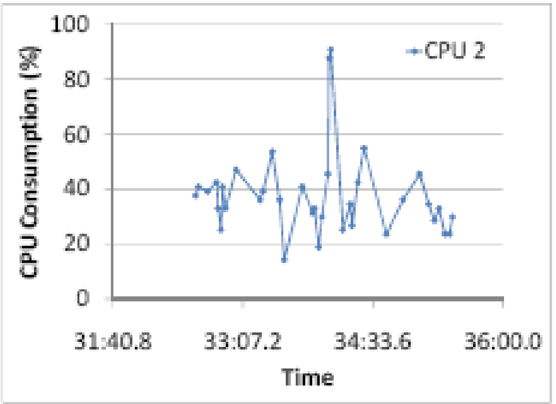
Reduced processing time from 19 seconds to less than 2 seconds

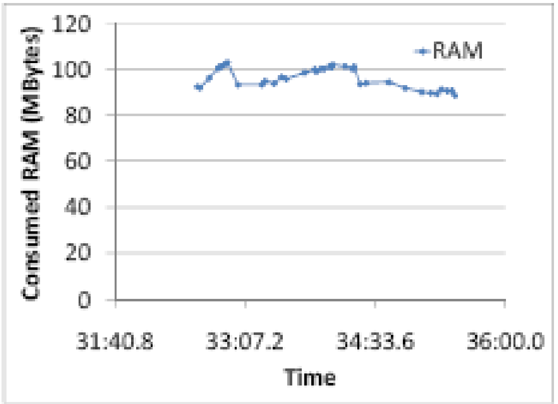
Offloads one method "Move Complex"

Offloads two methods "Select Piece" and "Move Piece"
Overhead of "Select Piece" is high

[3] MAUI Results: Memory Requirements







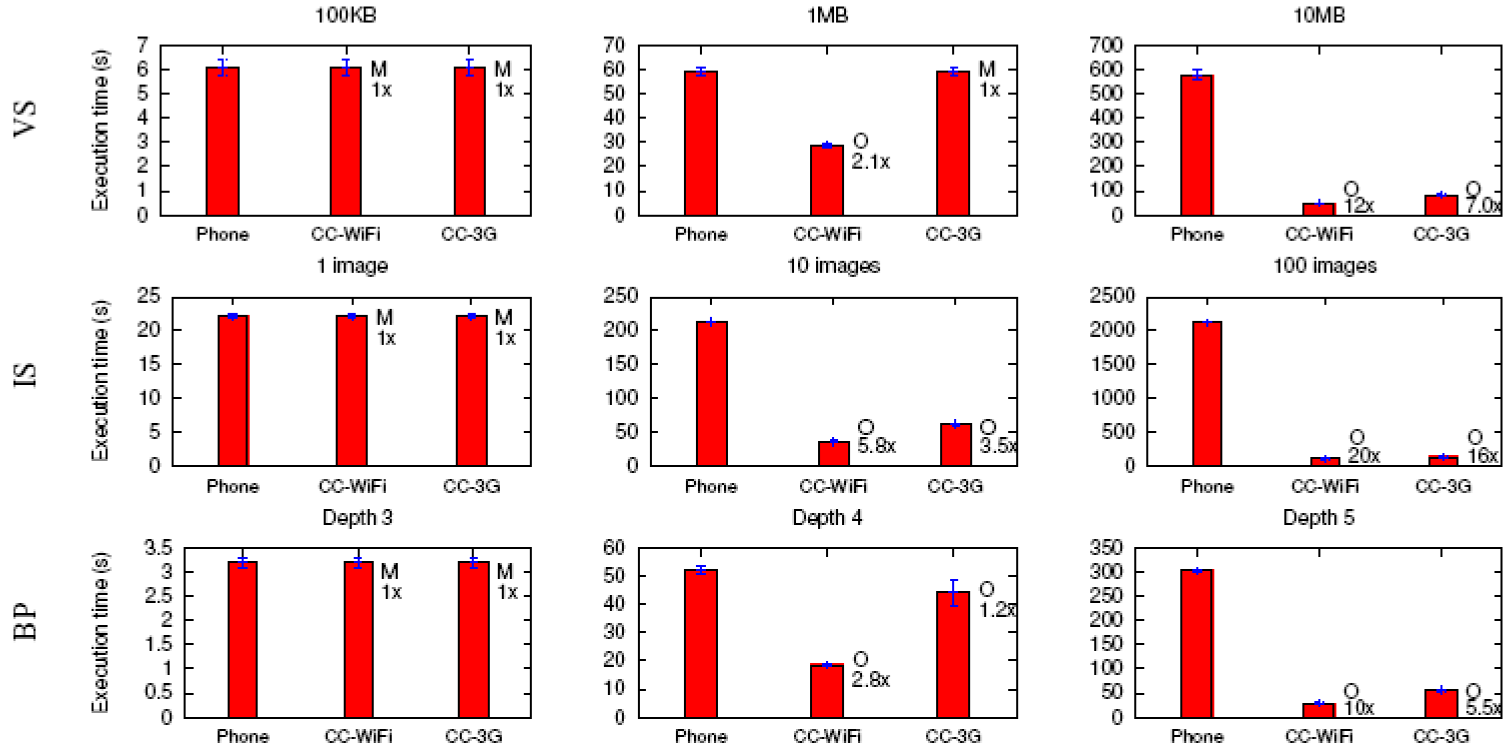
CPU and memory utilization of running a translator application on a PC
Peak memory consumption was 110 MB ➔ impossible to run on a smartphone with 32 MB smartphone RAM)

Using MAUI, the memory limitations can be overcome

CloneCloud: Test Applications

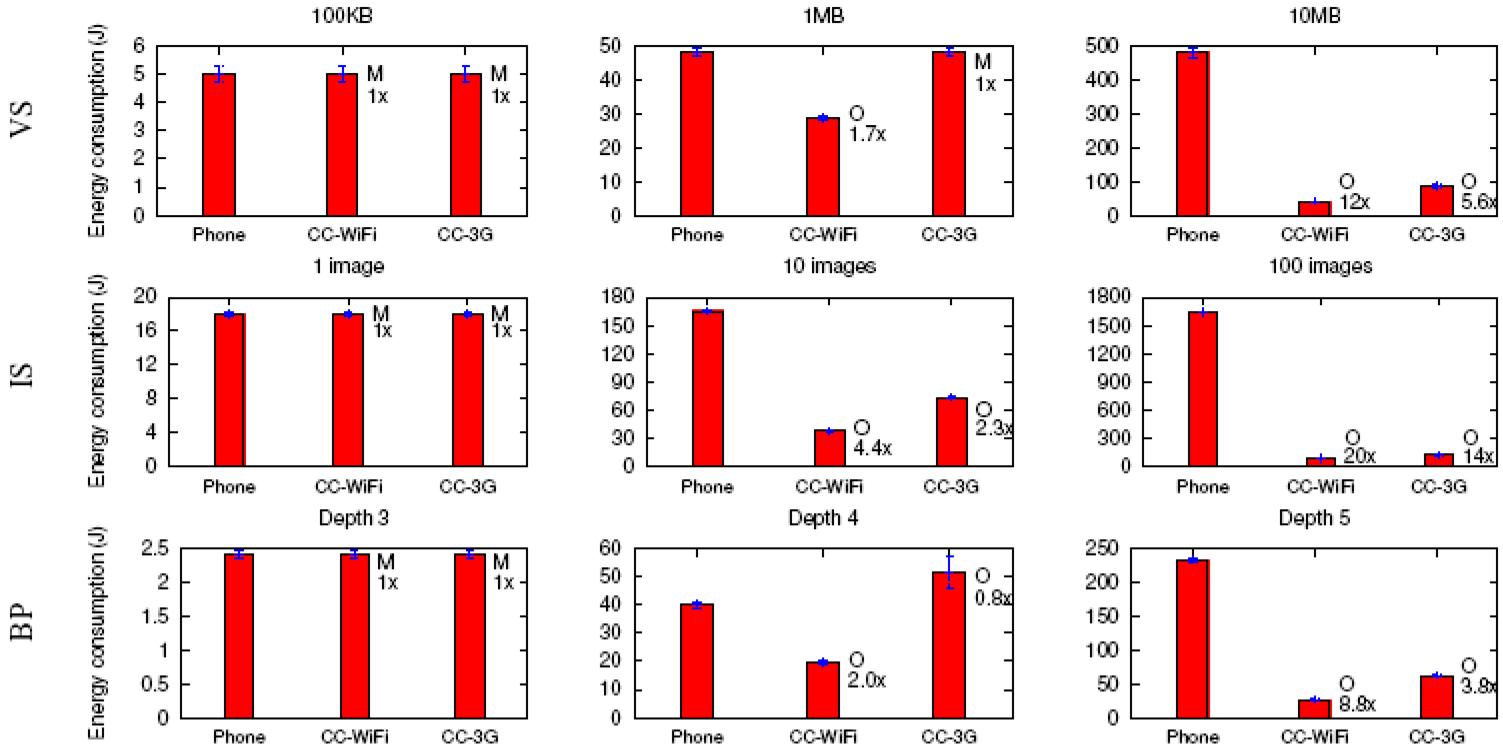
- Virus Scanning
  - Scans the content of the phone file system and matches against a library of 1000 signatures, one file at a time
- Image Search
  - Finds all faces in images stored in the phones using a face-detection library
- Privacy preserving targeted advertising
  - Uses behavioral tracking across websites to infer user's preferences on the smartphone (protects user's privacy) ➔ keyword matching problem

[1] CloneCloud Evaluation



Mean Execution Time for each application

[2] CloneCloud Evaluation



Mean Energy Consumption for each application

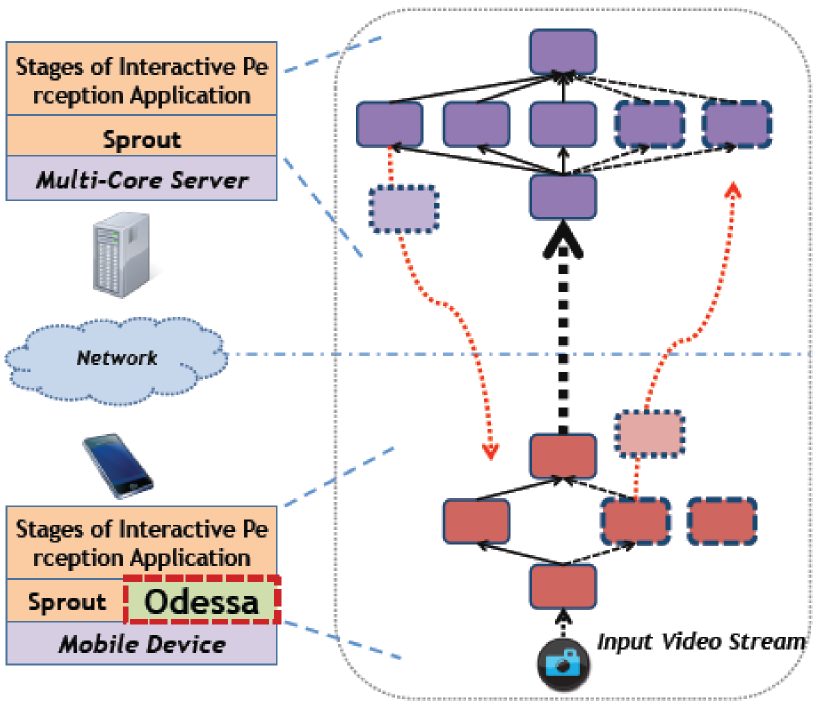
Interactive Perceptual Applications

- Applications that use camera and other high data rate sensors on smartphones for continuous sensing
  - Continuous face or object detection
  - Human machine interfaces
  - Interactive augmented reality experience

- Key requirements
  - Quick response
  - Continuous processing of high fidelity sensors
  - Compute intensive processing (ML, Comp. Vision)
  - Algorithm performance highly dependent on data

Conceptually similar to data parallel streaming applications

Overview of ODESSA system



Application	# of Stages	Avg. Makespan & Frame Rate
Face Recognition	9	2.09 s, 2.50 fps
Object and Pose Recognition	15	15.8 s, 0.09 fps
Gesture Recognition	17	2.54 s, 0.42 fps

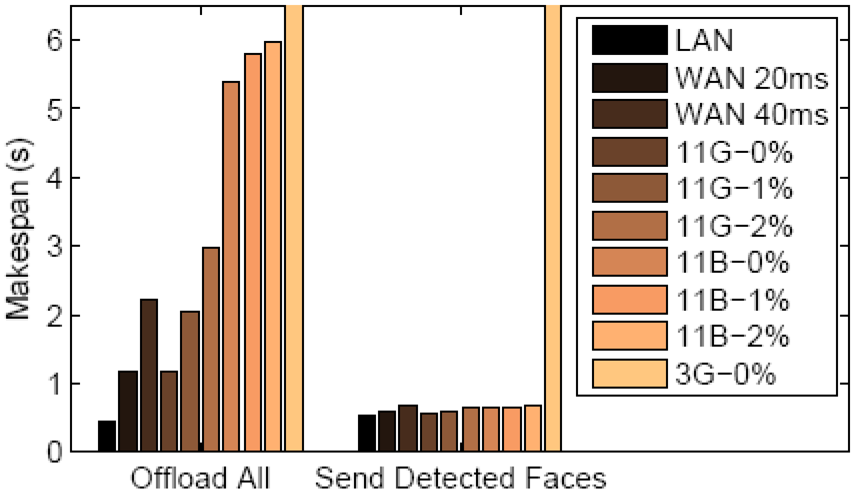
- Makespan is the time taken to execute all stages of a dataflow graph for a single frame
- Throughput is the rate at which frames are processed ➔ related to frame rate

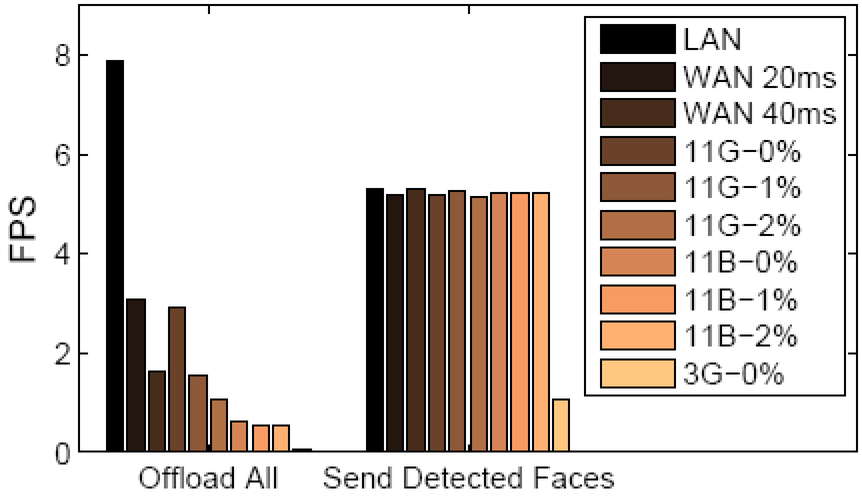
The idea is to exploit **offloading** and **degree of parallelism**

Three techniques to improve performance

- Offloading: move computationally intensive stages to server
- Pipelining: allow different stages to process different frames
- Increase data-parallelism: split frames into multiple sub-frames

[1] ODESSA Results

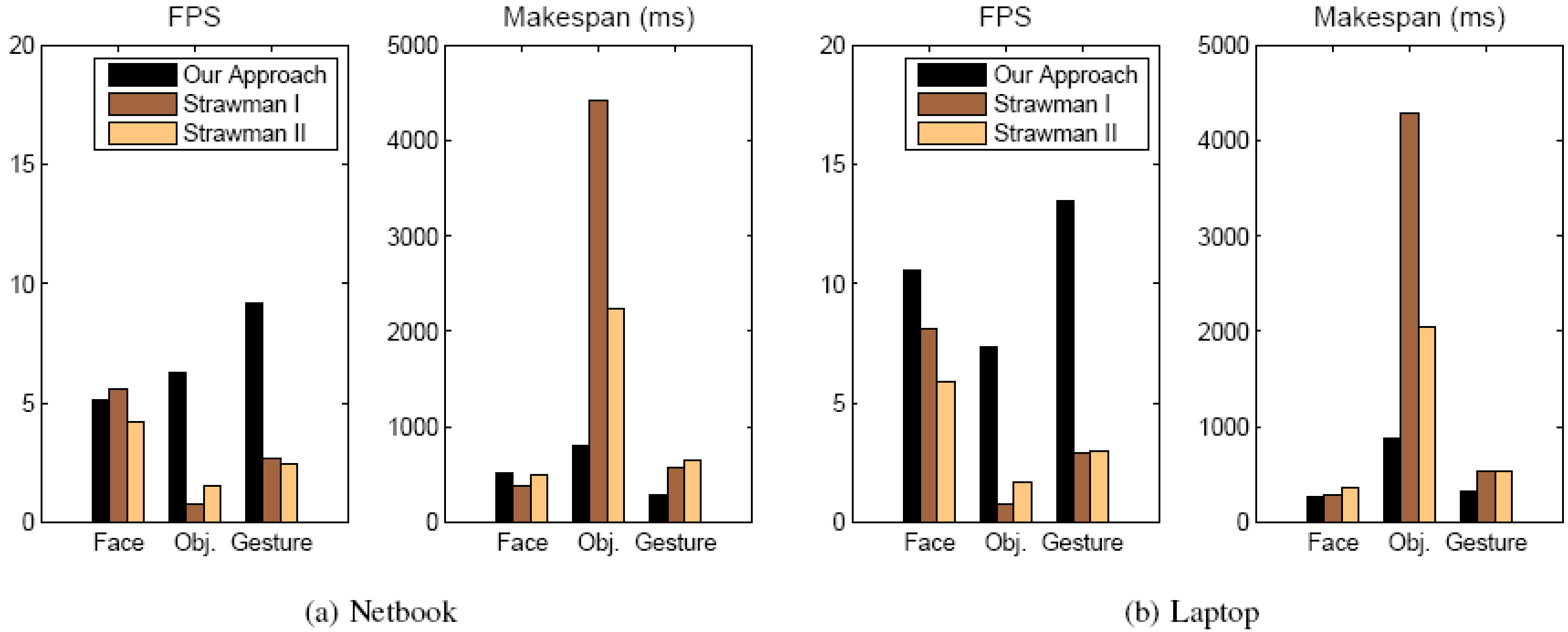




Large image transfer is very sensitive to even a small amount of delay and loss leading to significant performance loss
Even a loss-less 802.11g link cannot support more than 3 fps

Lesson: Simply offloading compute intensive task does not help

[2] ODESSA Results



Strawman I: Offload-All strategy where only video source stage and display runs locally, and a single instance of all other stages are offloaded to server

Strawman II: Domain-specific partitioning, where knowledge about application and input from developer is used to identify compute intensive stages in application graph

Both are static partitioning techniques

Offload Shaping

- The idea that sometimes it is valuable to perform additional cheap computation, not part of the original pipeline, on the mobile device in order to modify the offloading workload

- Scanarios
  - Object detection on a continuous video stream: If the video frame is blurry due to motion, then it is not useful to send it for processing
    - Detect blurry frame and discard ➔ blur detection possible using on-board sensors at low energy cost
  - If there is similarity across frames, then do not send the frames across ➔ the result of CV algo will not change significantly
  - If one wants to detect the Coke can in a scene, then filtering for Red color can indicate if a coke can may be there ➔ application context is exploited

(a) Sharp

(b) Blurry

Communication Intensive Apps

- Most popular apps involve intensive communication that consumes a significant part of the energy
  - Does offloading help in saving energy for such apps

- Key insight:
  - Reduce network traffic that is handled by mobile device → offload methods that handle communication with a server
  - Optimize traffic patterns → aggregate traffic across applications or within an application

Result on Twitter App

Measurement	Wi-Fi (avg/stdev)		3G (avg/stdev)	
	Original	Offloaded	Original	Offloaded
Total energy (measured)	2.67/0.59 J	25% less/0.3 J	3.92/1.97 J	18% more/2.1 J
Execution time for refresh to complete (measured)	2.69/0.59 s	6% more/0.5 s	3.86/2.02 s	33% more/2.1 s
Total traffic size (measured)	7.7/0.8 kB	17% less/0.5 kB	6.0/2.1 kB	31% less/1.8 kB
Energy used for network transmissions (estimated using model)	-	46% less/0.04 J	-	33% more/2.0 J

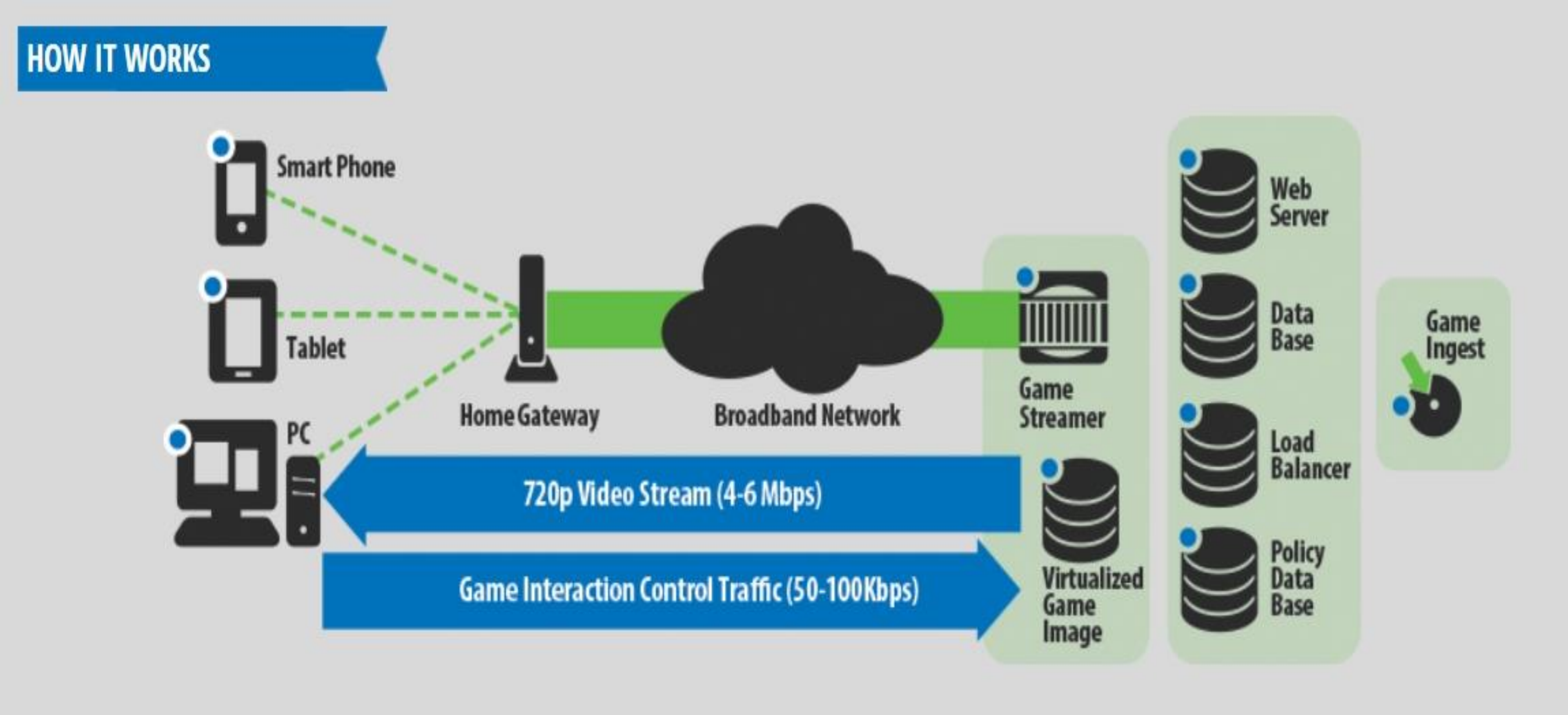
Used opensource Twitter app – AndTweet
Offloaded the communication intensive methods

It is non-trivial to identify the cases where communication offloading will definitely benefit

Extension of Communication offloading idea

- Mobile browsing
    - How to split the page load over cellular network to minimize energy consumption on the mobile device ?
    - Can you proritize/serialize content download while browsing

Cloud Gaming



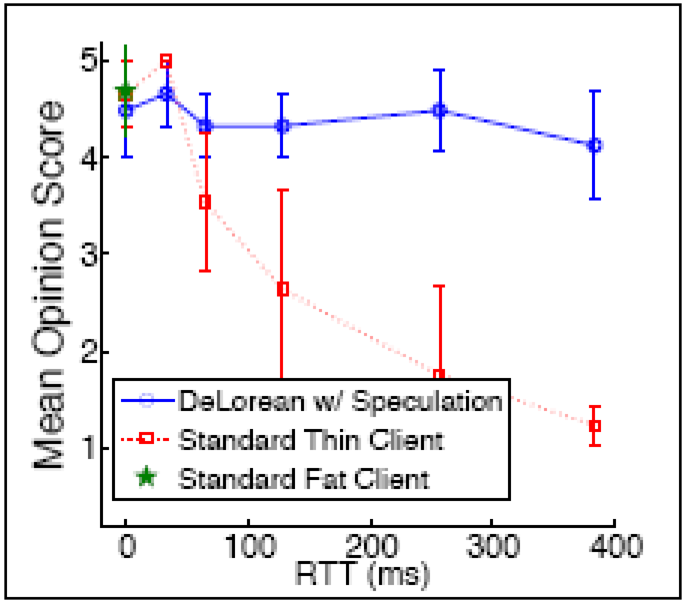
Several commercial providers – OnLive, AMD Game Servers

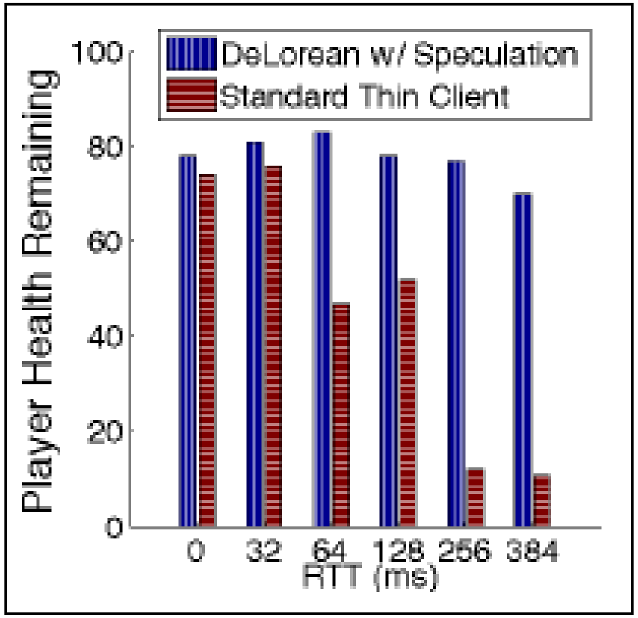
Cloud Gaming

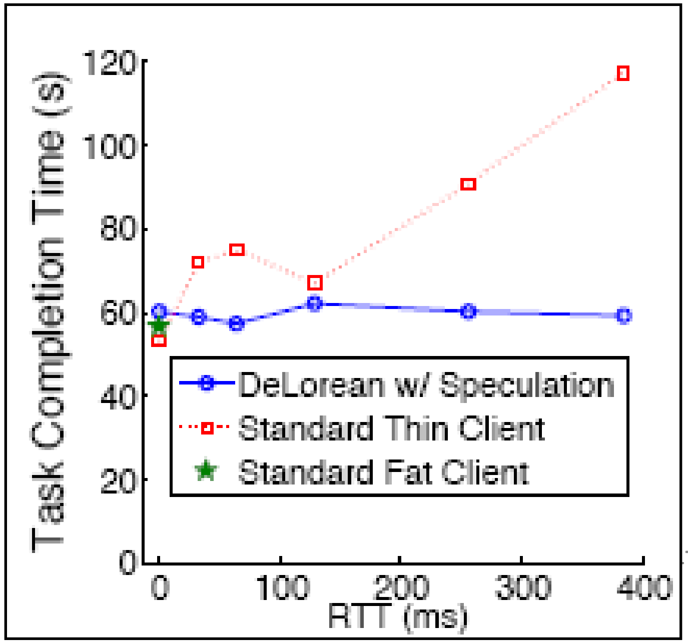
- Higher than 100 ms RTT makes interactive game play experience suffer
- Problem:
  - Rendering and transmission from server takes long since frame size can be large
  - Game input always comes from mobile device end
- Solution
  - Speculative Execution: Produce speculative rendered frames of future possible outcomes, and deliver them to client one RTT ahead of time

- Tested on Doom3 and another action-based role playing game

Results







Improved Game Play significantly

References

1. Ra, Moo-Ryong, et al. "Odessa: enabling interactive perception applications on mobile devices." *Proceedings of the 9th international conference on Mobile systems, applications, and services*. ACM, 2011.
2. Saarinen, Aki, et al. "Can offloading save energy for popular apps?."*Proceedings of the seventh ACM international workshop on Mobility in the evolving internet architecture*. ACM, 2012.
3. Hu, Wenlu, et al. "The case for offload shaping." *Proceedings of the 16th International Workshop on Mobile Computing Systems and Applications*. ACM, 2015.
4. Li, Jiwei, et al. "Make Smartphones Last A Day: Pre-processing Based Computer Vision Application Offloading."
5. Sivakumar, Ashiwan, et al. "PARCEL: Proxy Assisted BRowsing in Cellular networks for Energy and Latency reduction." *Proceedings of the 10th ACM International on Conference on emerging Networking Experiments and Technologies*. ACM, 2014.
6. Barbera, Marco, et al. "Mobile offloading in the wild: Findings and lessons learned through a real-life experiment with a new cloud-aware system."*INFOCOM, 2014 Proceedings IEEE*. IEEE, 2014.
7. Dubey A, et al. "ScoDA: Cooperative Content Adaptation Framework for Mobile Browsing." *Mobile Data Management (MDM), 2014 IEEE 15th International Conference on*. Vol. 1. IEEE, 2014.
8. Lee, Kyungmin, et al. "Outatime: Using speculation to enable low-latency continuous interaction for mobile cloud gaming." *Proc. of MobiSys*. 2015.