An Overview of Our Network Research

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Mobile Computing and Networking (MCN) Lab

- MCN lab conducts research in many areas of wireless networks and mobile computing, emphasis on designing and evaluating mobile systems, protocols, and applications.
  - Current Projects: wireless networks, mobile systems, Internet of Things, wireless security and privacy
  - Support: NSF, Army Research Office, NIH/CDC, DoD/Muri, DoD/DTRA, PDG/TTC and member companies Cisco, Narus, Telcordia, IBM and 3ETI.
- Current students:
  - 10 PhD students
  - 2 visiting scholars
  - 2 MS students

Alumni

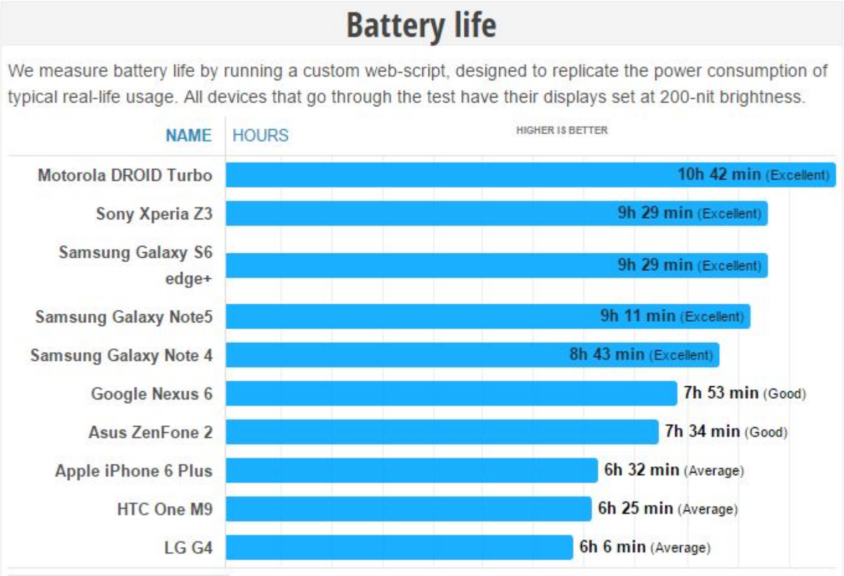
- 19 PhDs
  - Hao Zhu (8/2004), Qualcomm.
  - Liangzhong Yin (12/2004), Microsoft.
  - **Wensheng Zhang (8/2005), Associate Professor, Iowa State University**
  - **Hui Song (8/2007), Assistant Professor, Frostburg State University**
  - Jing Zhao (8/2008), Cisco Systems.
  - Min Shao (12/2008), Microsoft
  - Changlei Liu (5/2010), UMUC
  - Yang Zhang (2/2011), Palo Alto Networks.
  - Baojun Qiu (Co-chaired with J. Yen) 8/2011, eBay.
  - Bo Zhao (10/2011), AT&T.
  - Zhichao Zhu (2/2012), Nokia.
  - Qiang Zheng (5/2012), Google
  - **Wei Gao (5/2012), Assistant Professor, University of Tennessee.**
  - **Qinghua Li (5/2013), Assistant Professor, University of Arkansas.**
  - Yi Wang (5/2013), Google.
  - Jing Zhao (PhD, 9/2014), Google.
  - Wenjie Hu (PhD, 2/2016), Microsoft.
  - **Xiaomei Zhang (PhD, 5/2016), University of South Carolina, Beaufort.**
  - Xiao Sun (PhD, 9/2016), Facebook.
- 14 MS students went to various companies
- 5 visiting scholars

Outline

- Efficient Energy-Aware Data Access in Wireless Networks
  - Energy-aware computation offloading
  - Energy-aware Web Access
  - Energy-aware video streaming
- Resource-Aware Crowdsourcing
- Other projects

Background

- Battery is still the bottleneck of smartphone
  - Last for several hours for typical real-life usage
  - A breakthrough in battery technology seems unlikely

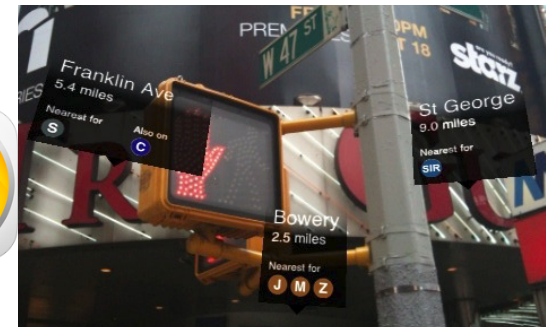


Design Energy-Aware Protocols and Systems

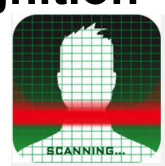
Background (con'd)

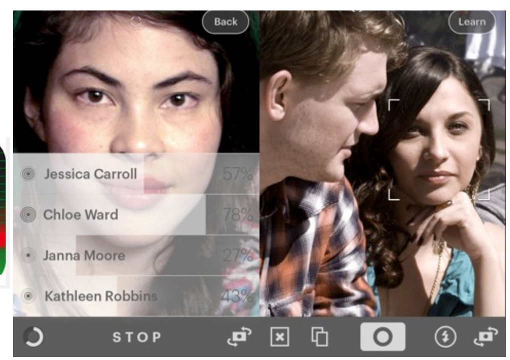
- Processing & storage capabilities are making significant improvements
  - Computationally intensive applications are increasing


Speech Recognition

Augmented Reality



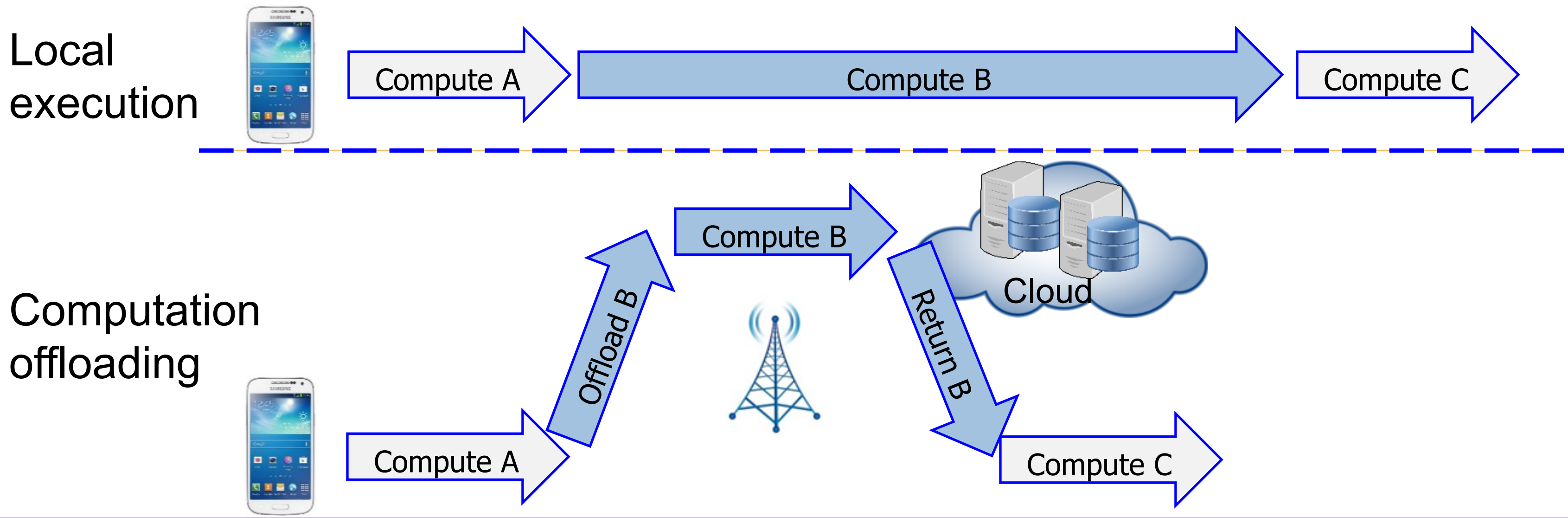


Face Recognition

Computationally intensive applications can quickly deplete the battery.

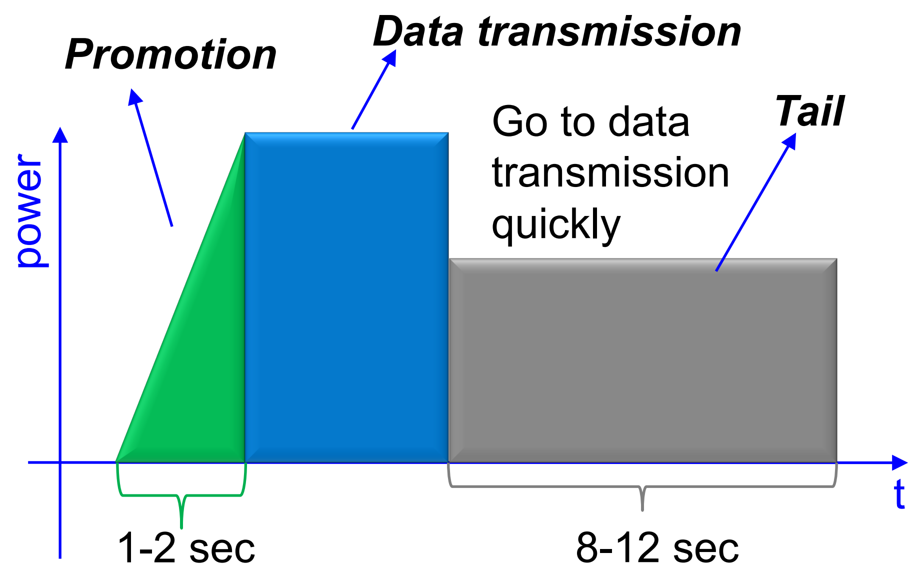
A viable solution: Computation Offloading

- Offload local computational tasks to resource-rich servers (e.g. cloud)
  - Benefit: improve performance & reduce energy consumption
  - **Cost: communication overhead**



Motivation

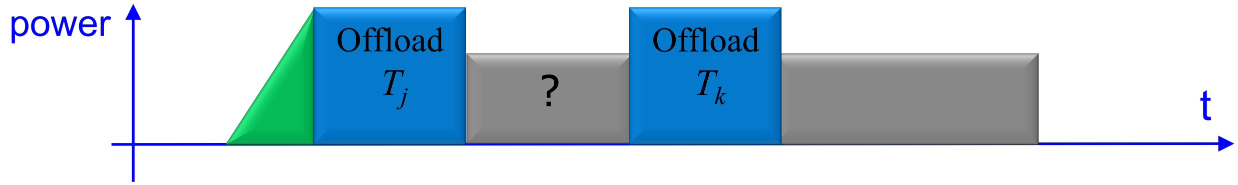
- Long tail problem in cellular networks
  - Power states
    - Promotion
    - Data transmission
    - Tail



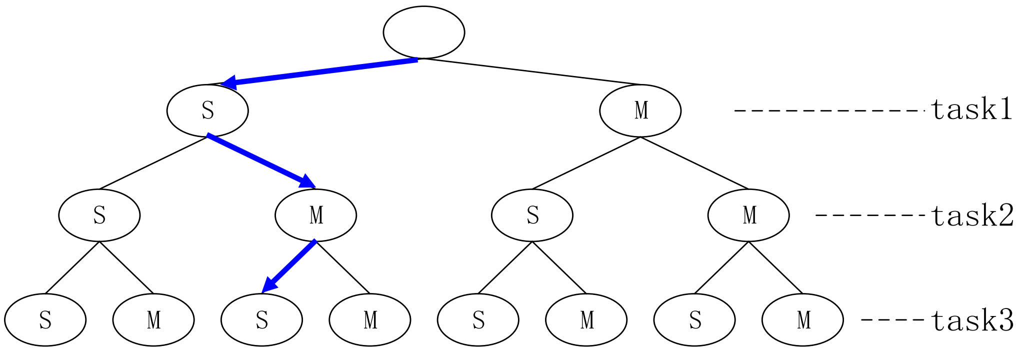
- Existing offloading solutions ignore the long tail problem
  - Offload a task when ***benefit* > ? *cost* + *tail energy***

Optimal Computation Offloading

- Given ***n*** sequential computational tasks, what is the **best offloading decision** to **minimize the energy?**
- Challenge



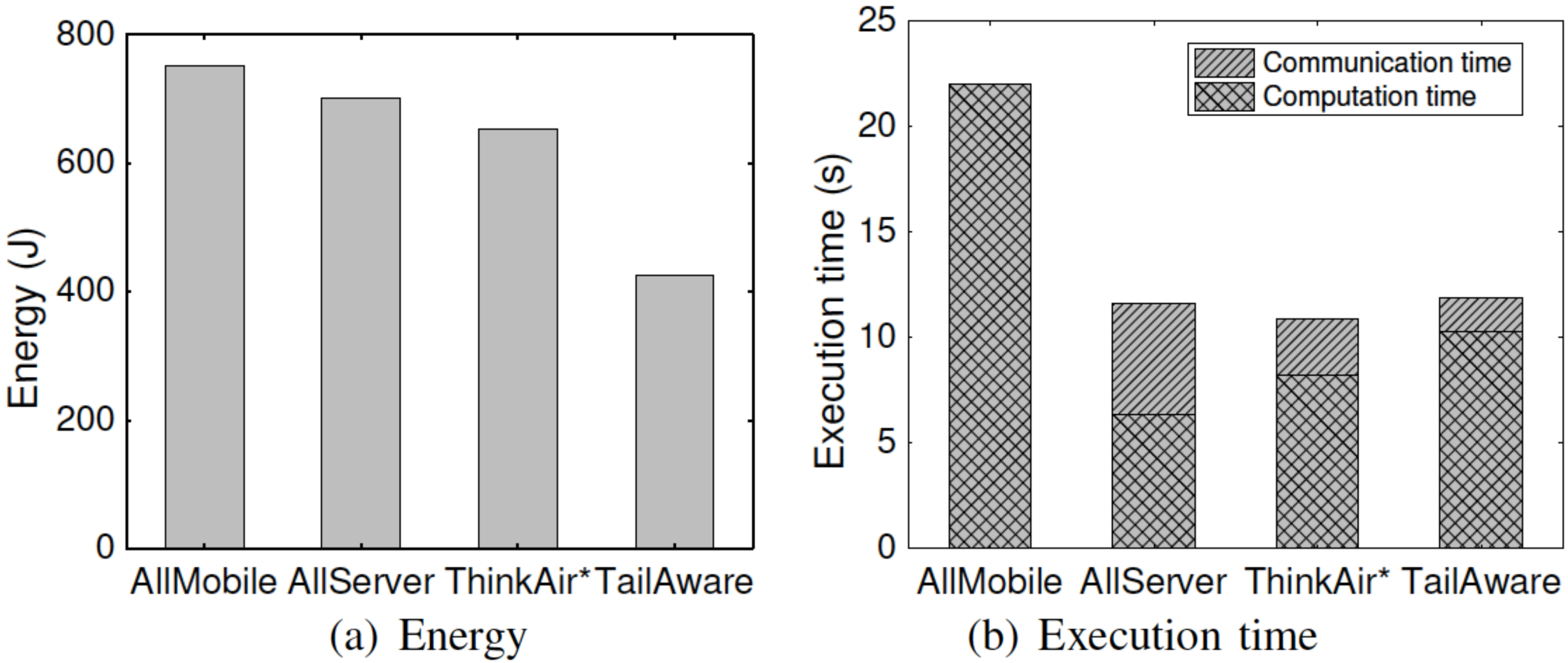
  - Cost of offloading a task cannot be estimated independently
  - T_k's energy depends on its location & previous offloaded task
- A naïve solution



Decision states for a task increase exponentially.

Testbed Evaluation

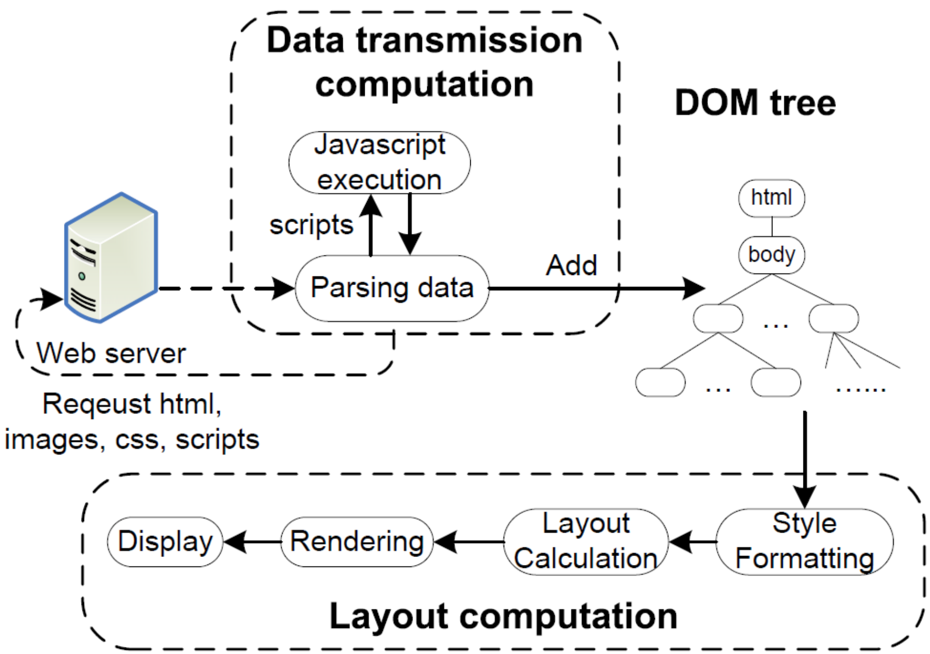
- Samsung Galaxy with LTE data plan, OCR application to automatically recognize the characters in images and output the text

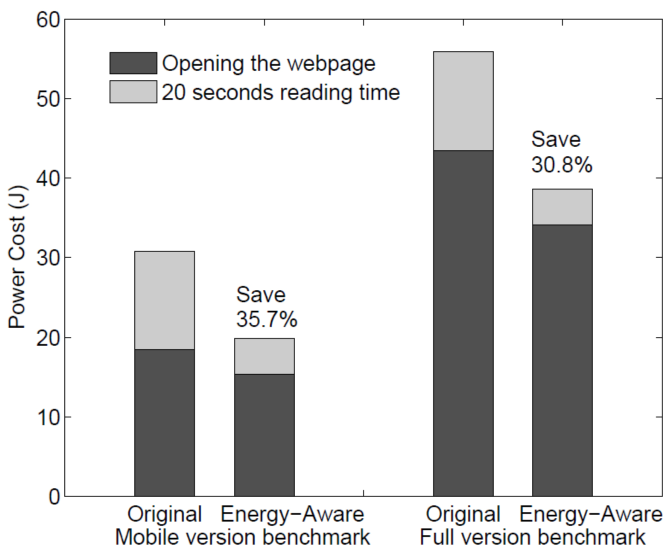


- Energy saving rate
  - 43% AllMobile / 39% AllServer / 34% ThinkAir

Energy-Efficient Web Browsing

- Reorganize the computation sequence of the web browser, so that it first runs the computations that will generate new data transmissions and retrieve these data from the web server.
  - Then, the web browser can put the wireless interface into low power state, and then run the remaining computations.
- After a webpage is downloaded, predict the user reading time on the webpage using Gradient Boosted Regression Trees (GBRT).

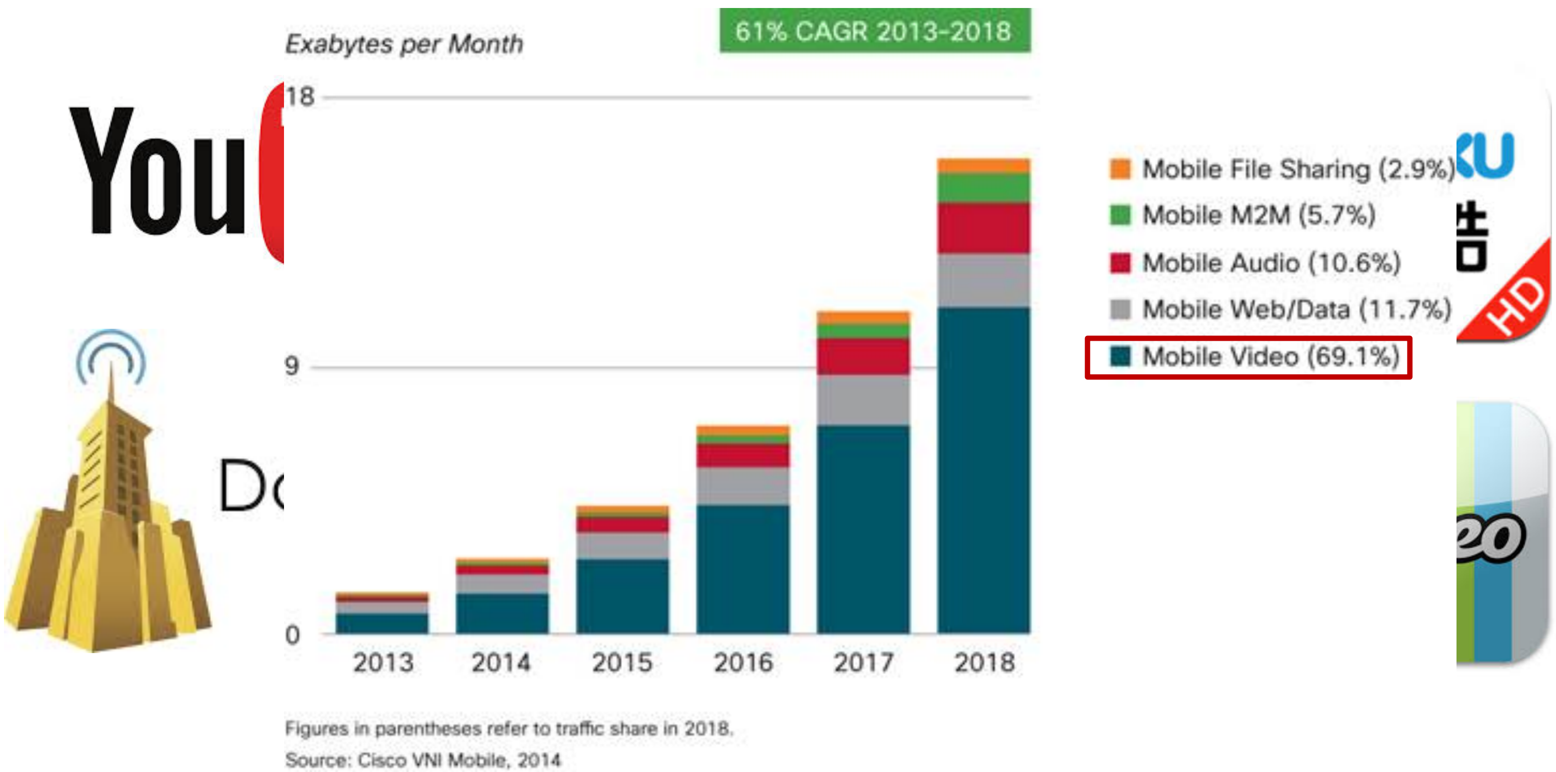




ICDCS'14, TPDS'15

Mobile Video Streaming

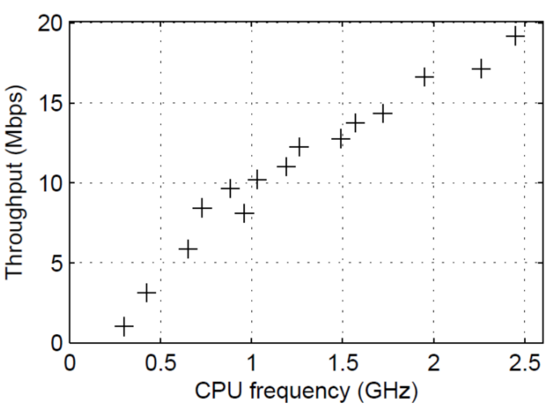
- Video streaming has become the largest data traffic on mobile devices



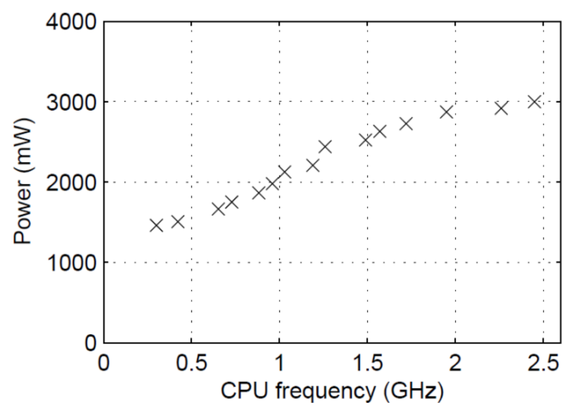
Source: Cisco Virtual Network Index

CPU Frequency Scaling

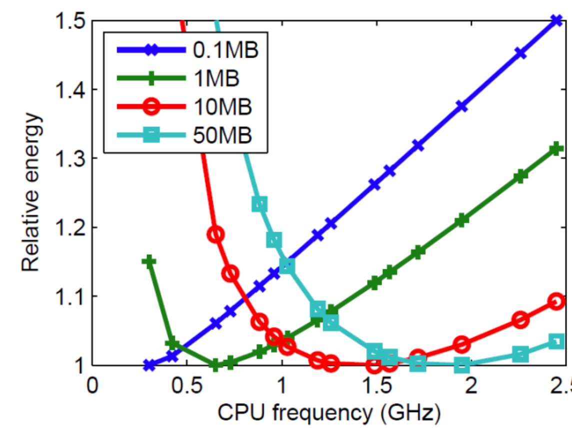
- To address the challenge of how to download
- Reduce the total energy of mobile video streaming by adaptively adjusting the CPU frequency.
  - Considering the effects of CPU frequency on TCP throughput and power consumption.



(a) Throughput



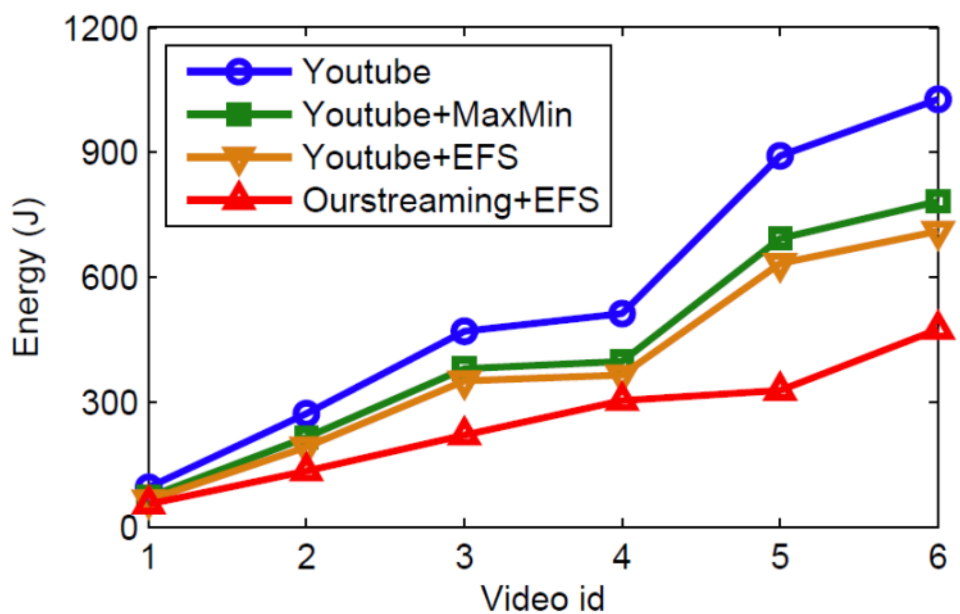
(b) Power consumption



(c) Energy to download a chunk of data

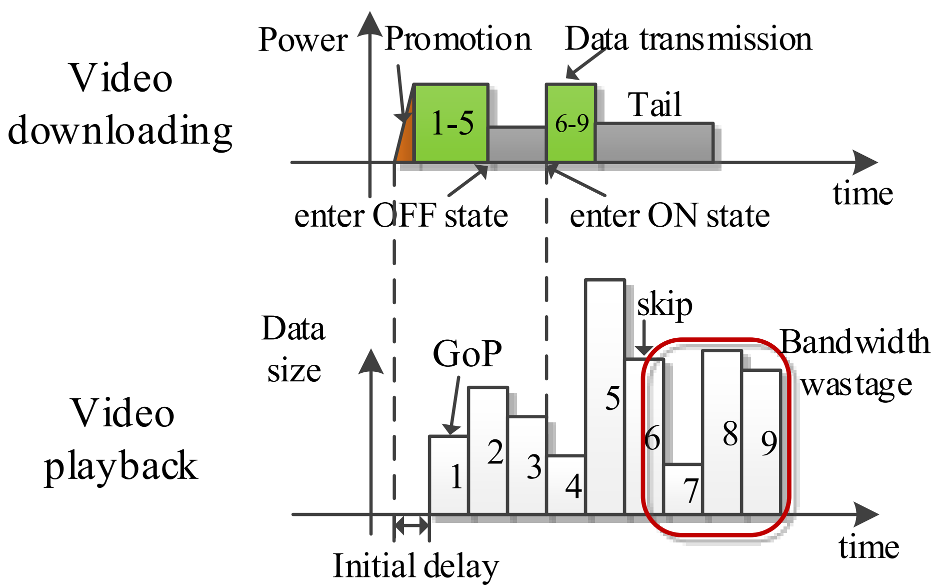
Energy-Aware CPU Frequency Scaling

- Youtube: default interactive CPU governor to adjust the CPU frequency.
- Youtube+MaxMin: the highest CPU frequency during data transmission and the minimum CPU frequency without data transmission.
- Youtube+EFS: the Youtube app using our Energyaware Frequency Scaling algorithm (EFS) to adjust CPU frequency.
- Ourstreaming+EFS: the combination of optimized downloading schedule and the EFS algorithm. The buffer size is set to 10 MB.



Buffer Management

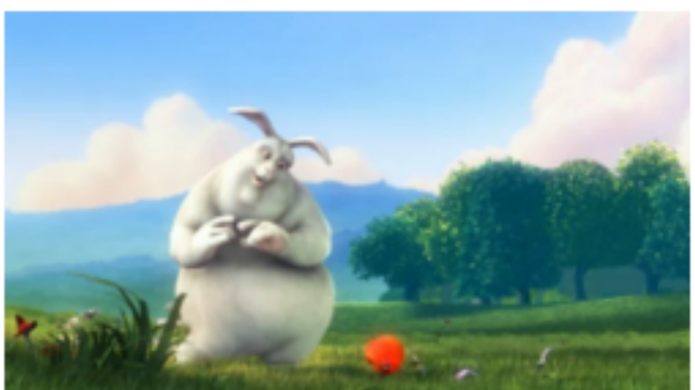
- ON-OFF scheme
  - Buffers lots of data and then turn the wireless interface off
  - Introduces more bandwidth wastage when a user skips
- Bitrate streaming
  - Downloads the video at the playback rate
  - Consumes more energy and introduces more delay

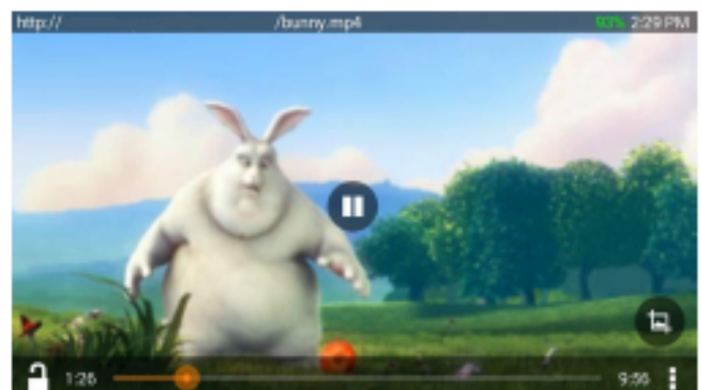


(a) ON-OFF

Buffer Management

- To address the challenge of how much to download, we introduce methods to predict whether a user tends to skip when watching a video.
- Based on the prediction result, different techniques are applied.
  - an optimized ON-OFF scheme in stable mode
  - a modified bitrate streaming in unstable mode

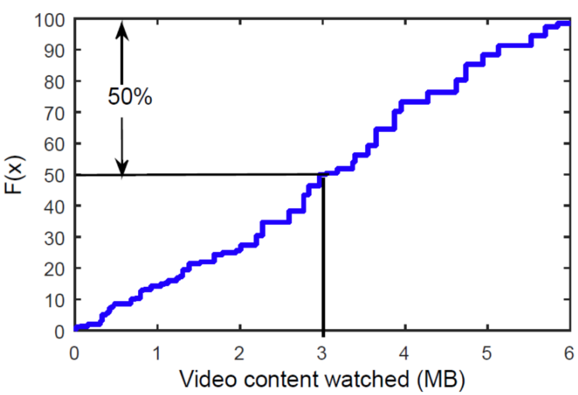

(a) Stable mode

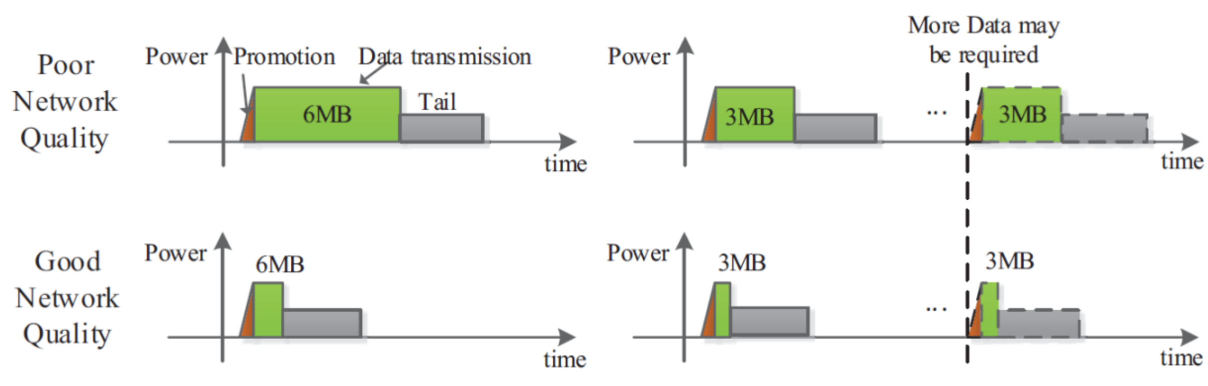


(b) Unstabe mode

Network Quality Aware Downloading:

- To address the challenge of when and how much to download
  - Find a downloading schedule that minimizes the energy consumption of data transmission under the current network quality. (Dynamic Adaptive Streaming over HTTP (DASH) protocol)





(a) Downloading option 1 (b) Downloading option 2

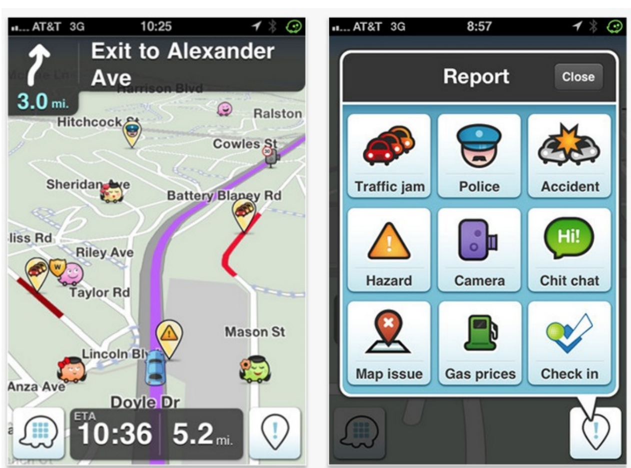
- Under poor network quality, option 1 consumes 2×60+10 = 130 joules, and option 2 consumes 2×30+10+ 0.5 *(2×30+10) = 105 Joules
- Under good network quality, option 1 consumes 16 joules, option 2 consumes 19.5 joules.

Outline

- Efficient Energy-Aware Data Access in Wireless Networks
- Resource-Aware Crowdsourcing
  - SmartPhoto
  - VideoMec
- Other projects

Mobile Crowdsourcing

- Mobile crowdsourcing allows data gathering/sharing through smartphones
  - Waze app
  - Smart city/community



SmartPhoto

Photos from tourists

Map server

Limited processing power

Virtual tours

Limited bandwidth

Command center

Recovery plan

Key challenge: resource limitation

Mobihoc'14, icdcs'16, infocom'17

VideoMec

- Crime investigation

Crime scene

Mobile videos

Surveillance videos

First responders / Further investigation

Command center

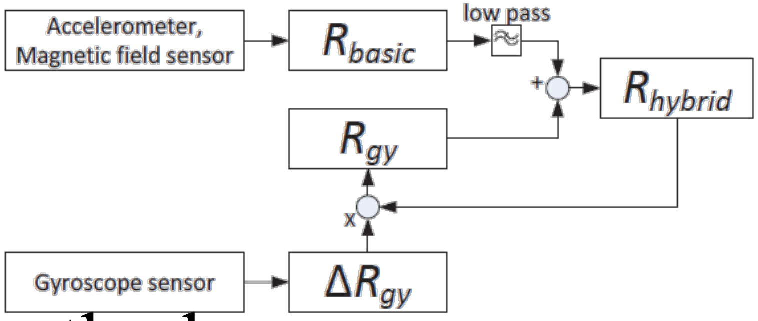
- Others
  - Locating a missing child, investigating traffic accidents, reporting news, military applications, etc.

Existing Approaches

- Content-based
  - Upload all videos to cloud/cloudlets and analyze them using computer vision algorithms
  - High resource consumption: redundancy/storage, processing, bandwidth
- Description-based
  - Generate video descriptions and only upload the descriptions for video search
  - Inconvenient to tag manually; miss important information, e.g., a suspect caught in a tourist's video, but labeled as tour related
- Video metadata based
  - Automatically generate time, location, camera orientation, camera field of view, camera range, resolution, and other metadata as video descriptions

Improving Orientation Accuracy

- Hybrid method



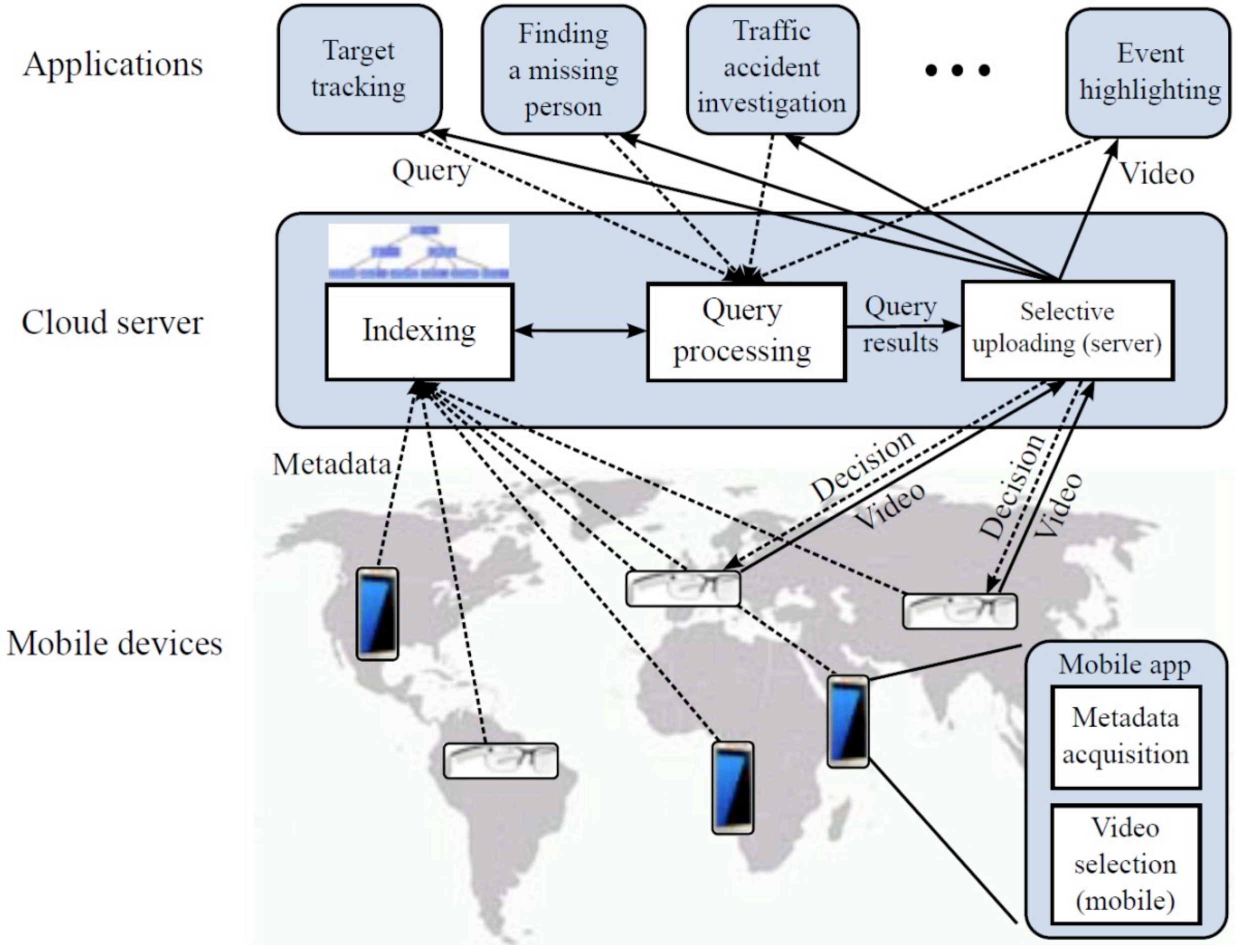
- Enhanced method
  - Calibrate the result of hybrid method by an ortho-normalization process
- Results

Table 1: Average error in azimuth (degree)

	Nexus S	Nexus 4	Galaxy S III
Basic	9.1(±2.0)	8.2(±1.5)	9.6(±2.4)
Hybrid	5.7(±1.9)	5.1(±1.3)	7.3(±1.7)
Enhanced	3.4(±1.4)	1.3(±0.7)	3.4(±1.3)

Challenges

- Scalable metadata indexing (R* tree in GIS)
- Comprehensive video query (filter-refine paradigm)
- Limited video uploading bandwidth, especially for time-sensitive or bandwidth-sensitive applications (select important parts; complementary to content-based approach).



IPSN'17

Outline

- Efficient Energy-Aware Data Access in Wireless Networks
- Resource-Aware Crowdsourcing
- Other projects
  - Exploiting Embedded Sensors in Smartwatches for Health Monitoring
  - Privacy Disclosure Through Smart Meters: Reactive Power Based Attack and Defense

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Adversarial Network Forensics in Software Defined Networking

Stefan Achleitner, Thomas La Porta, Trent Jaeger, Patrick McDaniel

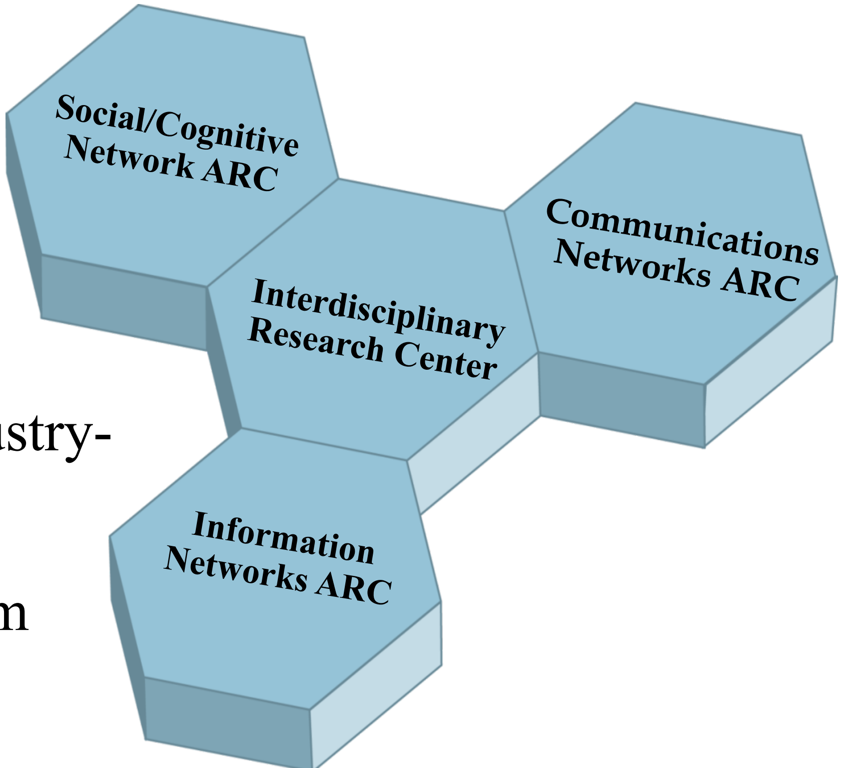
PennState College of Engineering | INSTITUTE FOR NETWORKING AND SECURITY RESEARCH

- A new attack on SDN by showing how the detailed composition of flow rules can be reconstructed by network users without any prior knowledge of the SDN controller or its architecture.
  - Achieved by performing active probing and listening to the network traffic.
  - Discuss ways to prevent the introduced reconnaissance techniques.

Network Science Collaborative Technology Alliance (NSCTA)

Enhance Army's network science, technology & research program and:

- Create a Sustainable World-Class Network Science facility with critical mass
- Strengthen & Exploit Government-Industry-Academia Partnerships
- Adopt a Multidisciplinary, Fill-Spectrum Approach
- Accelerate the Transition and Improve the Relevance of Army-Sponsored Research
- Tightly Couple Efforts at ARL & CERDEC

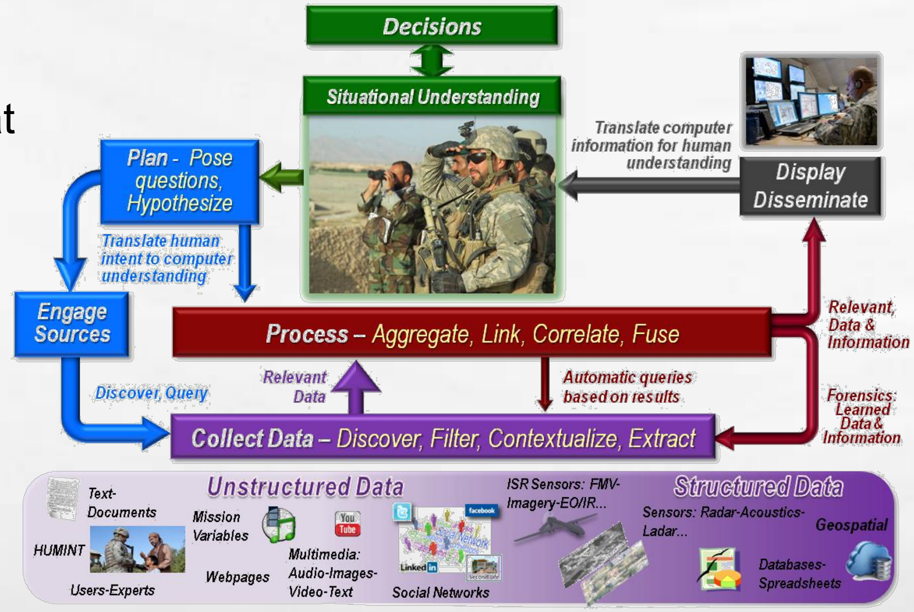


Quality of Information for Semantically-Adaptive Networks (QoI-SAN)

Goal: Understand how to control network behaviors in response to semantic requests in context so that the capacity of the network to deliver relevant information can be maximized

Approach:

- Treat Network as an Information Source that supports decision making
- Jointly study semantics, networking & information processing
- New formal definition of network capacity considering the semantic attributes of information
- Human intent of information requests translated into processable form & decomposed into actionable info strategies



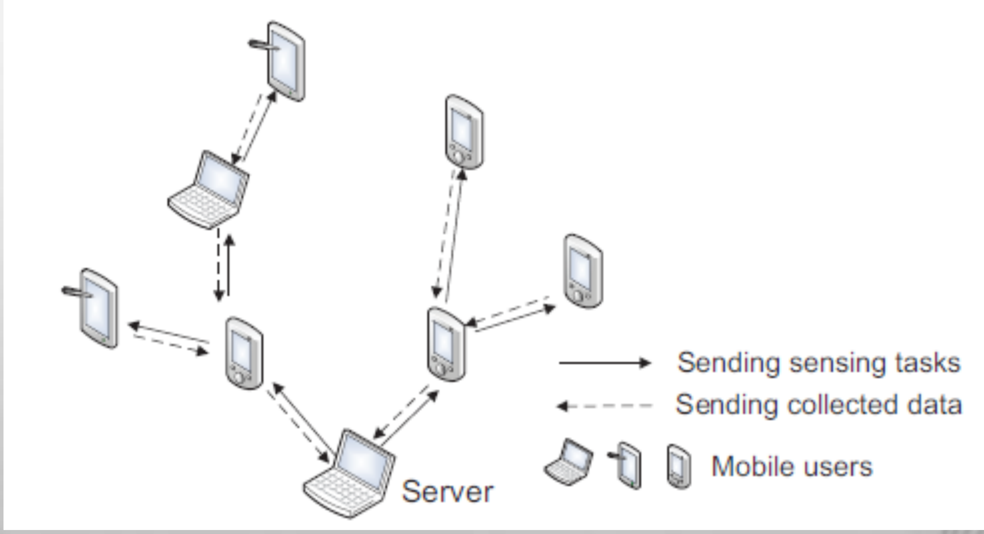
Task Leads: Tom La Porta

Organizations: ARL, BBN, CMU, CUNY, IBM, PSU, RPI, UCSB, UIUC, USC

Resource-Aware Approaches for Truth Analysis in social sensing

- Existing truth analysis:
  - Identify truth among conflicting claims based on information analysis techniques such as Maximum-likelihood estimation (MLE)
- Problems : hard to identify truth when
  - Available information or data are limited or have large conflicts
- Solution: utilize communication networks to adaptively collect multi-dimensions of information (data, image, video) from mobile users
  - Based on a feedback loop between information and communication network to collect the right information. (to verify some news related to ground troops, the information directly collected will be more convincing)
  - Improved data credibility (quality)
  - Increased cost in communication networks—tactical network

- Goal: quantify the tradeoff between the increased network overhead and the enhanced data credibility.
- **Max-credibility problem**:
  - Maximizing data credibility, network overhead below a specified value
- **Min-overhead problem**:
  - Achieving the specified credibility, minimizing the network overhead



Thank you!

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