Energy-Efficient Mobile Video Management using Smartphone

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23 February 2011

Outline

I. Introduction
II. Power Model
III. System Design
IV. Experimental Evaluation
V. Prototype
VI. Conclusions

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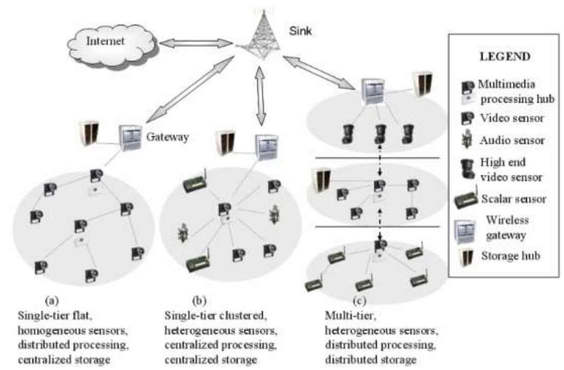
Mobile video with sensor data

- Affordable, portable, and networked video cameras make video applications feasible and practical
- Plain video sensor networks → Wireless multimedia sensor networks
- Capable of managing far more and diverse information from the real world
- Videos with associated scalar sensor data can be collected, transmitted, and searched
- Multimedia surveillance, environmental monitoring, industrial process control, and location based multimedia services

Motivation

Traditional  + sensor  + Network interface  + 

Now

Video capturing

Various sensors

WiFi

Handheld mobility

Challenges

- Capacity constraints of the battery

- Wireless bandwidth bottlenecks

- Searchability of online videos

  Open-domain video content is very difficult to be efficiently and accurately searched

Methods to make video content searchable

- Content-based video retrieval

  Difficult to achieve high accuracy

- Text annotation-based video retrieval

  Ineffective, ambiguous and subjective

- Sensor data-based video retrieval

  The concurrent collection of sensor generated geospatial contextual data

  Aggregate multi-sourced geospatial data into a standalone **metadata** tag

  → identify video content by
  a number of precise, objective geospatial characteristics

Ways to transmit both metadata and video jointly from a mobile device

- Immediate transmission after capturing through wireless network

  Immediate availability of the data

  Consume lots of energy and bandwidth

- Delayed transmission when a faster network is available

  Sacrifice real time access

  Minimum power

Mobile geo-referenced video management

- Framework to support an efficient mobile video capture and their transmission
- Observation: not all collected videos have high priority
- Core: separate the small amount of geospatial meta-data from the large video content
- Meta-data is transmitted to a server in real-time
- Video content is searchable by viewable scene properties established from meta-data attached to each video
- Video is transmitted in an on-demand manner

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linear-regression-based model

Parameters of the HTC G1 smartphone used in the power model

Hardware	Parameter	Coefficient (C_j)	Range (of β_j)
CPU	CPU_hi CPU_lo	$C_{CPU\_hi} = 3.97\ mW/\%$ $C_{CPU\_lo} = 2.79\ mW/\%$	$\beta_{CPU\_hi}: 0 - 100\%$ $\beta_{CPU_{lo}}: 0 - 100\%$
Screen	LCD Brightness	$C_{LCD} = 150\ mW$ $C_{br} = 2.07\ mW/step$	$\beta_{LCD}: 0, 1$ $\beta_{br}: 0 - 255\ steps$
WiFi	WiFi_on WiFi_trf WiFi_bytes	$C_{WiFi\_on} = 39\ mW$ $C_{WiFi\_trf} = 658.93\ mW$ $C_{WiFi\_bytes} = 0.518\ mW/byte$	$\beta_{WiFi_{on}}: 0,1$ $\beta_{WiFi\_trf}: 0,1$ $\beta_{WiFi\_bytes}: \geq 0$
Storage	SD	$C_{SD} = 0.0324\ mW/sector$	$\beta_{SD}: \geq 0$
GPS	GPS	$C_{GPS} = 430\ mW$	$\beta_{GPS}: 0,1$
System	System	$C_{System} = 169.08\ mW$	$\beta_{System}: 0,1$

The overall system power consumption as a function of time *t*

$$P(t) = \left(C_{CPU_{hi}} \times \beta_{CPU_{hi}}(t)\right) + \left(C_{CPU_{lo}} \times \beta_{CPU_{lo}}(t)\right) + \left(C_{LCD} \times \beta_{LCD}(t)\right) + \left(C_{Brightness} \times \beta_{br}(t)\right) +$$

$$\left(C_{WiFi_{on}} \times \beta_{WiFi_{on}}(t)\right) + \left(C_{WiFi_{trf}} \times \beta_{WiFi_{trf}}(t)\right) + \left(C_{WiFi_{bytes}} \times \beta_{WiFi_{bytes}}(t)\right) +$$

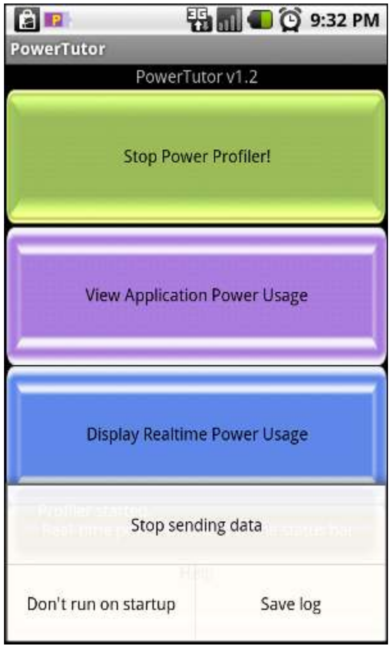
$$\left(C_{SD} \times \beta_{SD}(t)\right) + \left(C_{GPS} \times \beta_{GPS}(t)\right) + \left(C_{System} \times \beta_{System}(t)\right)$$

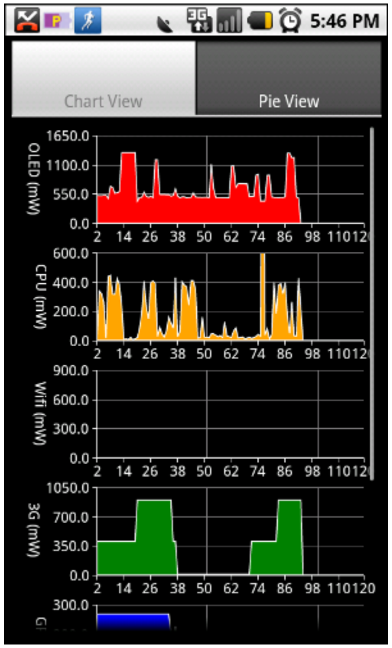
[A. Shye, B. Sholbrock, and G. Memik. Into The Wild: Studying Real User Activity Patterns to Guide Power Optimization for Mobile Architectures. In Micro, 2009.]

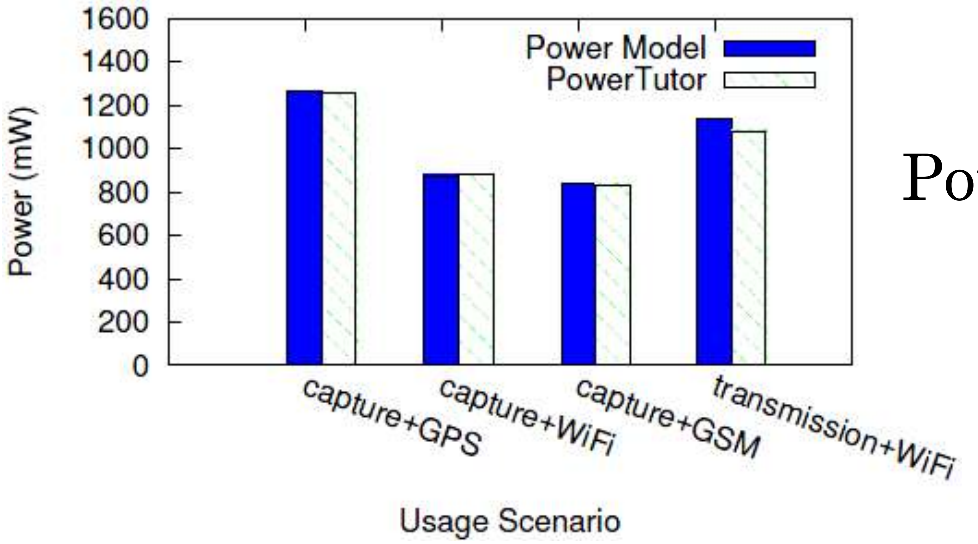
Validating Power Model

Screenshot of the PowerTutor

[B. Tiwana and L. Zhang. PowerTutor. http://powertutor.org, 2009.]







Power model vs. PowerTutor

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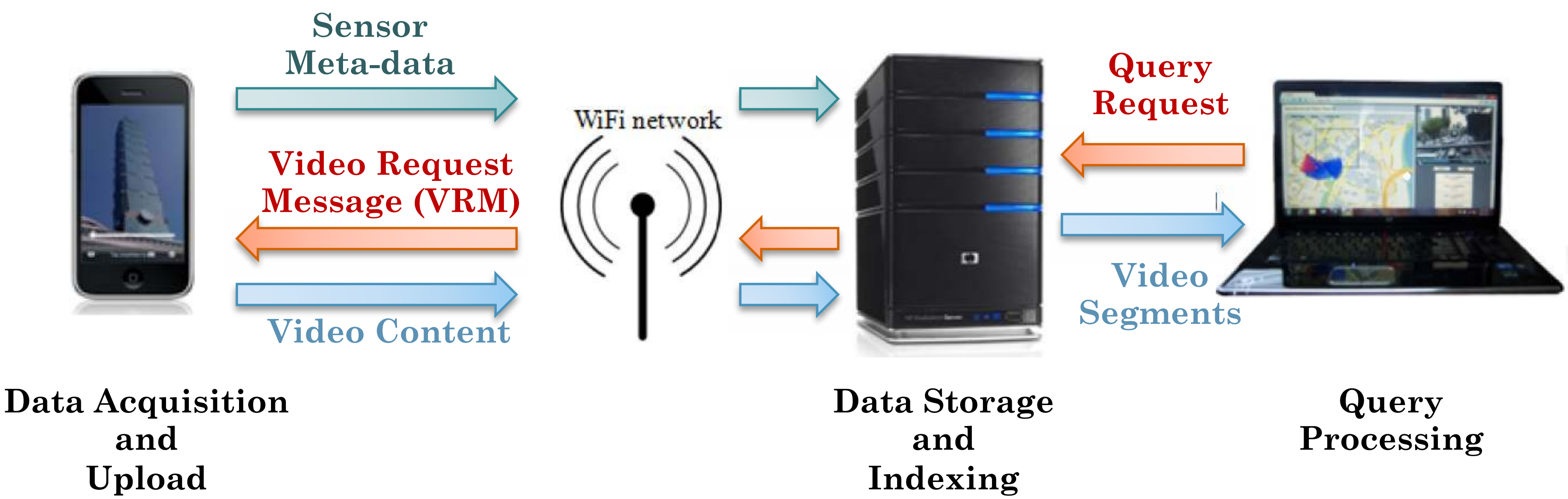
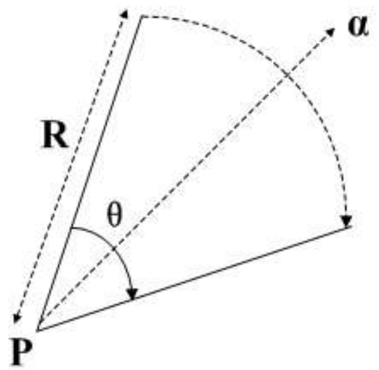
System environment for mobile video management



Key idea: save considerable battery energy by delaying the costly transmission of the video segments that have not been requested.

Field-of-View (FOV)



P<longitude,latitude>: camera location
θ:viewable angle
α:camera direction angle
R:visible distance

$$\langle nid, vid, t_{FOV}, t_f, P, \alpha, \theta, R \rangle$$

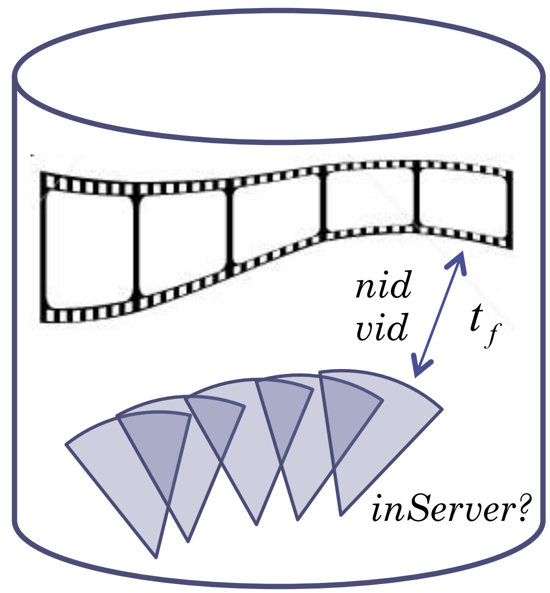
timecode

when the FOV is recorded

ID of video file

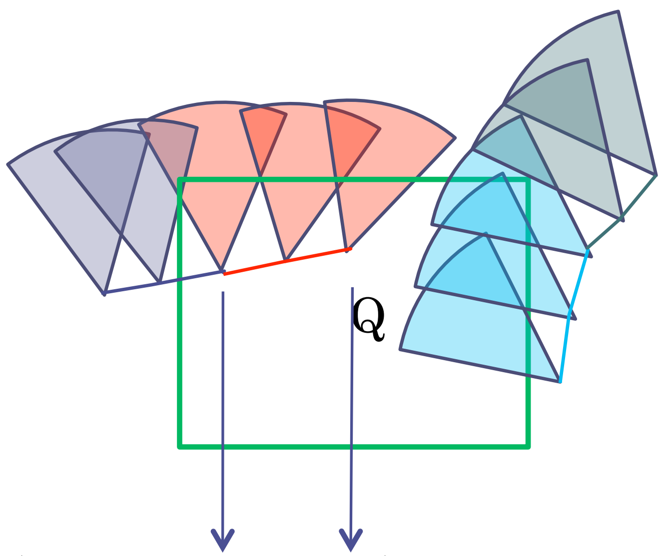
ID of mobile device

Storage Server

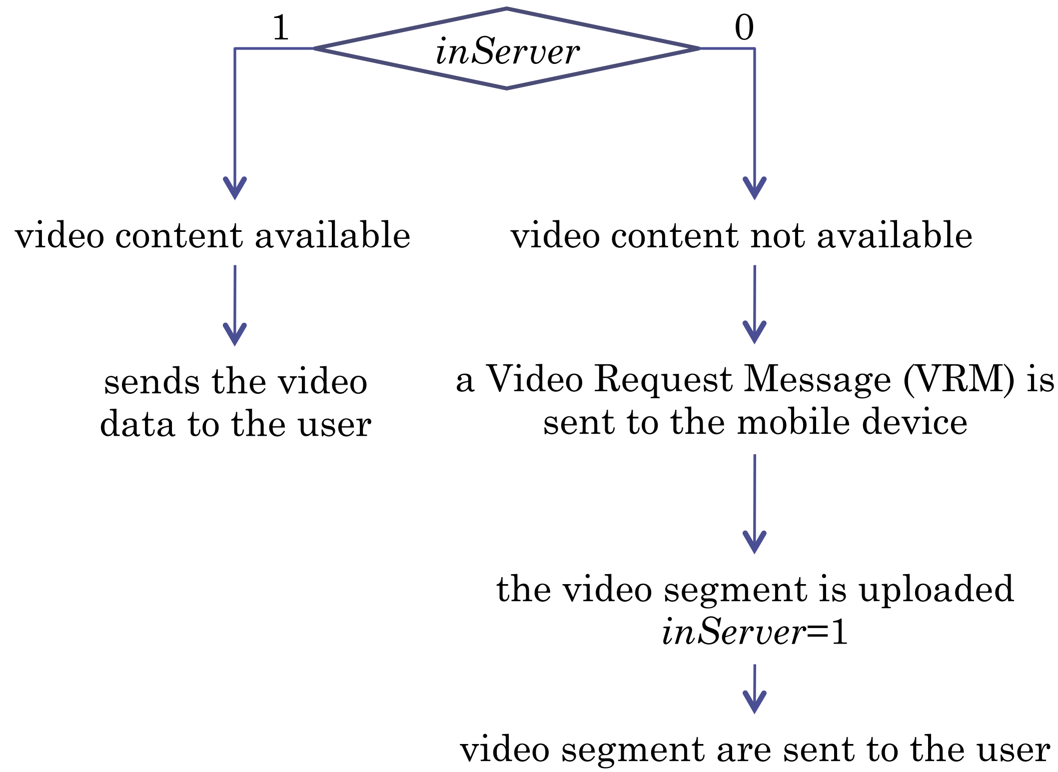


[S. Arslan Ay, R. Zimmermann, and S. H. Kim. Viewable Scene Modeling for Geospatial Video Search. In 16th ACM Intl. Conference on Multimedia, 2008.]

Query Processor



$$\langle nid, vid, t_{start}, t_{end} \rangle$$



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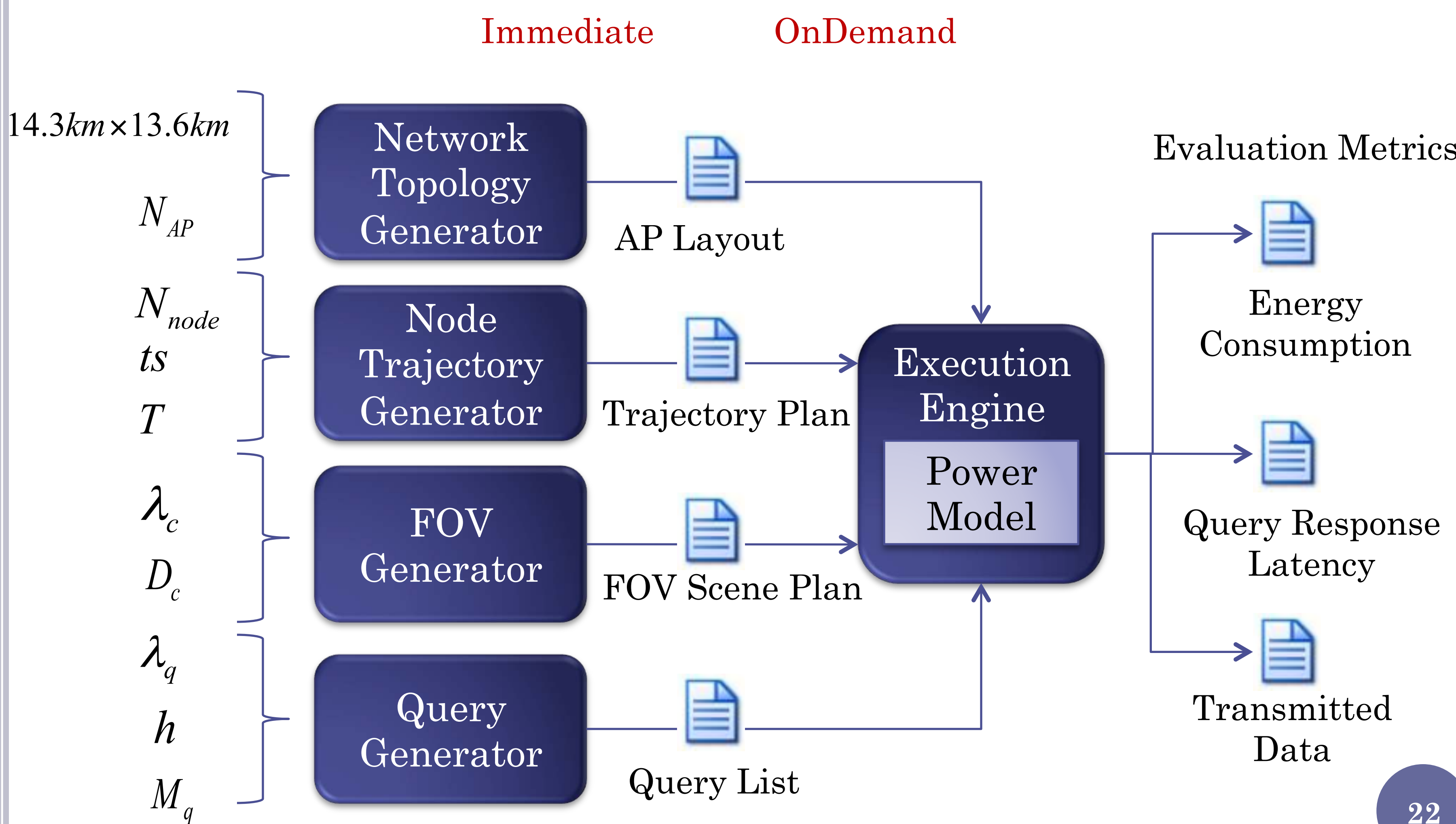
Simulator Overview

- Urban wireless communication infrastructure
- Mobile users are moving on the road network of San Francisco
- The users capture and transmit videos with predefined simulation models
- Some other users launch queries to retrieve the collected videos from the same region

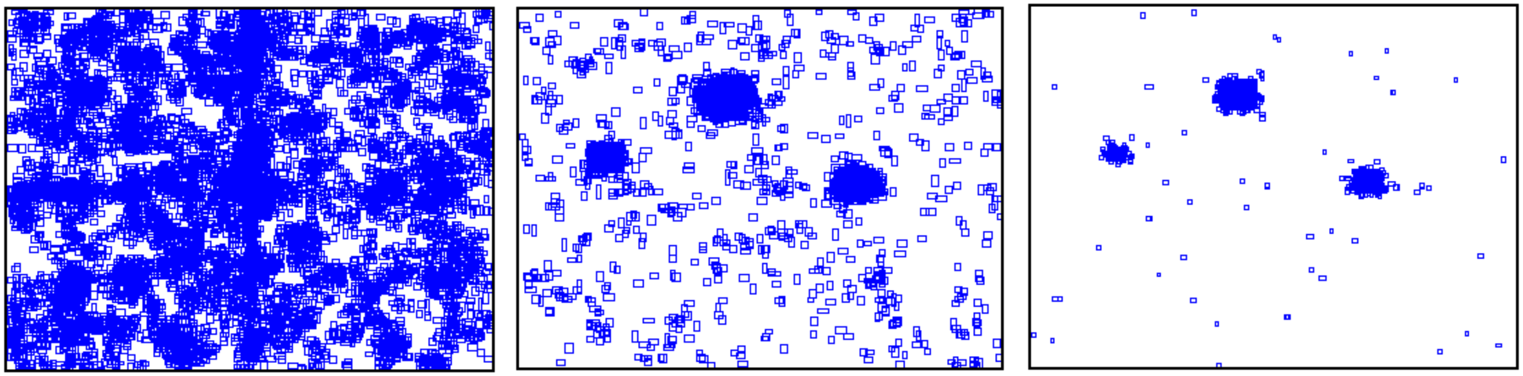
Simulator Architecture and Modules



[Brinkhoff. A framework for generating network-based moving objects. 02]

Query Model

Query workload: a list of query rectangles that are mapped to specific locations

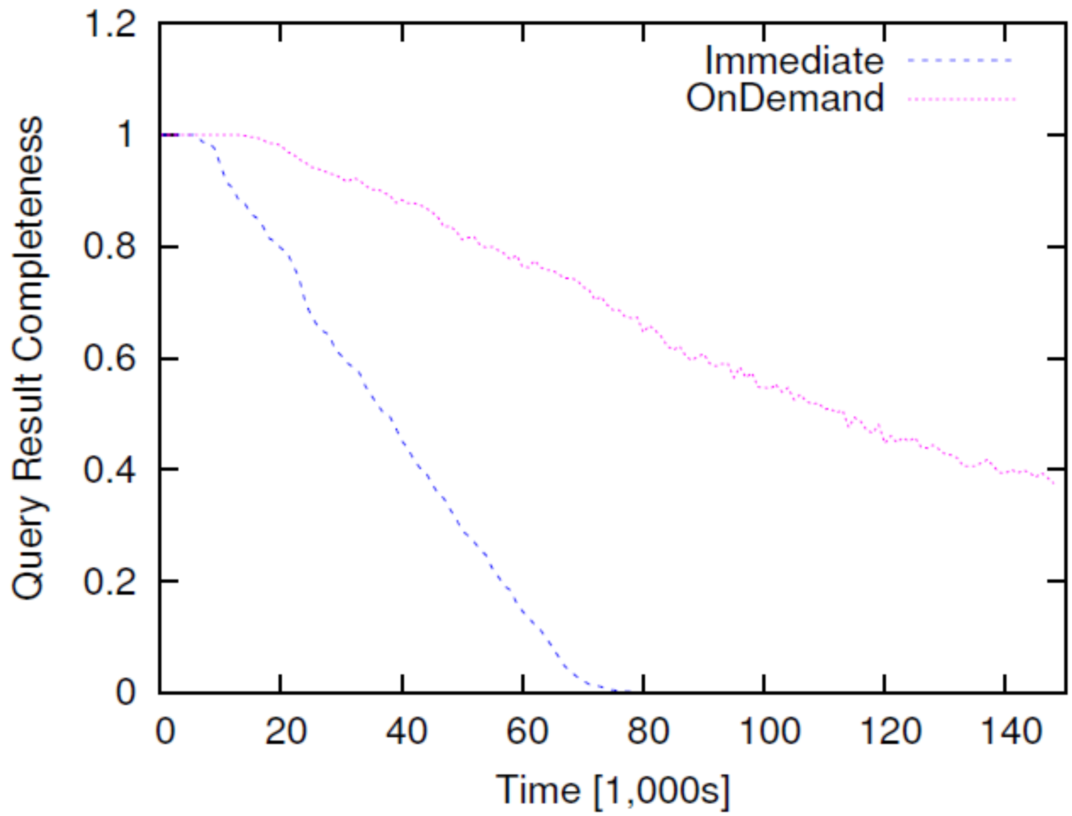


h=0 *h*=0.5 *h*=1

Spatial query distribution with three different clustering parameter *h*

Performance: Without Battery Recharging

closed system where batteries cannot be recharged

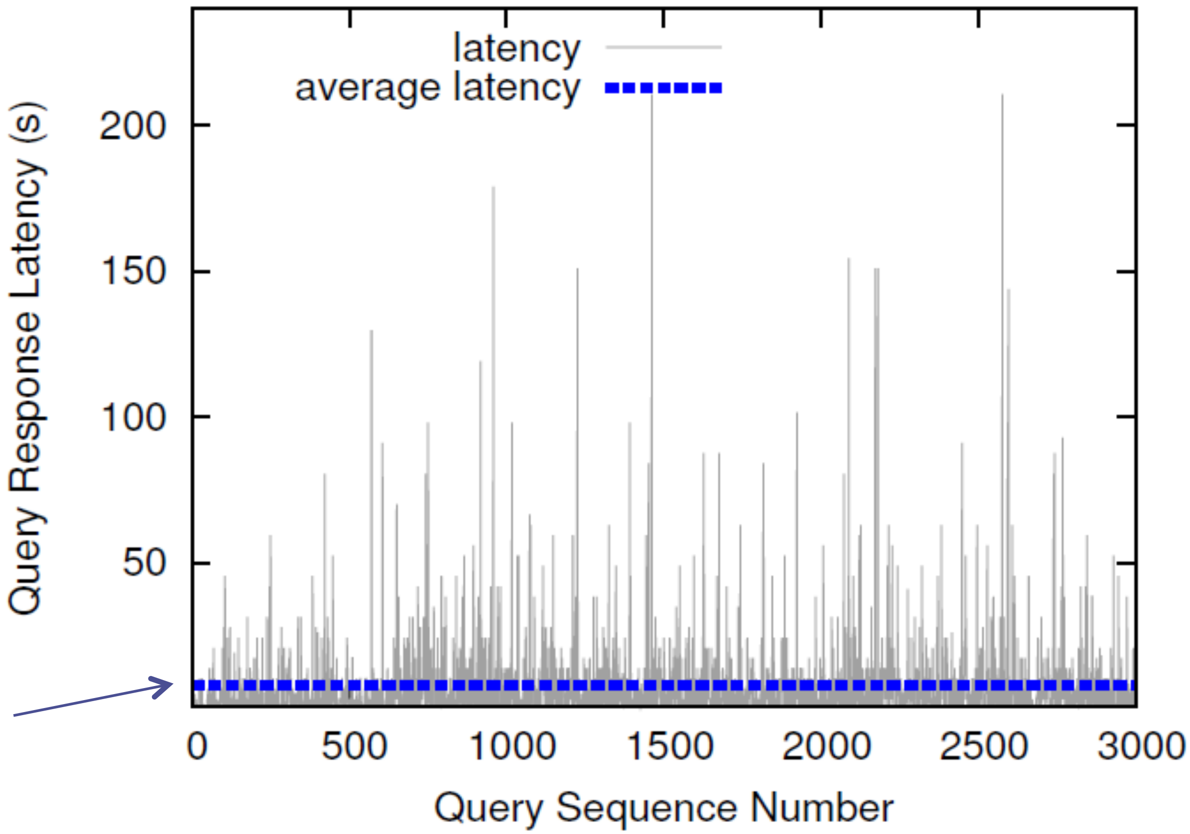


$$\frac{\text{Video segments actually returned}}{\text{Video segments that should be returned}}$$

Baseline: no battery constraints

Query result completeness (PDF) with N = 2, 000 nodes.

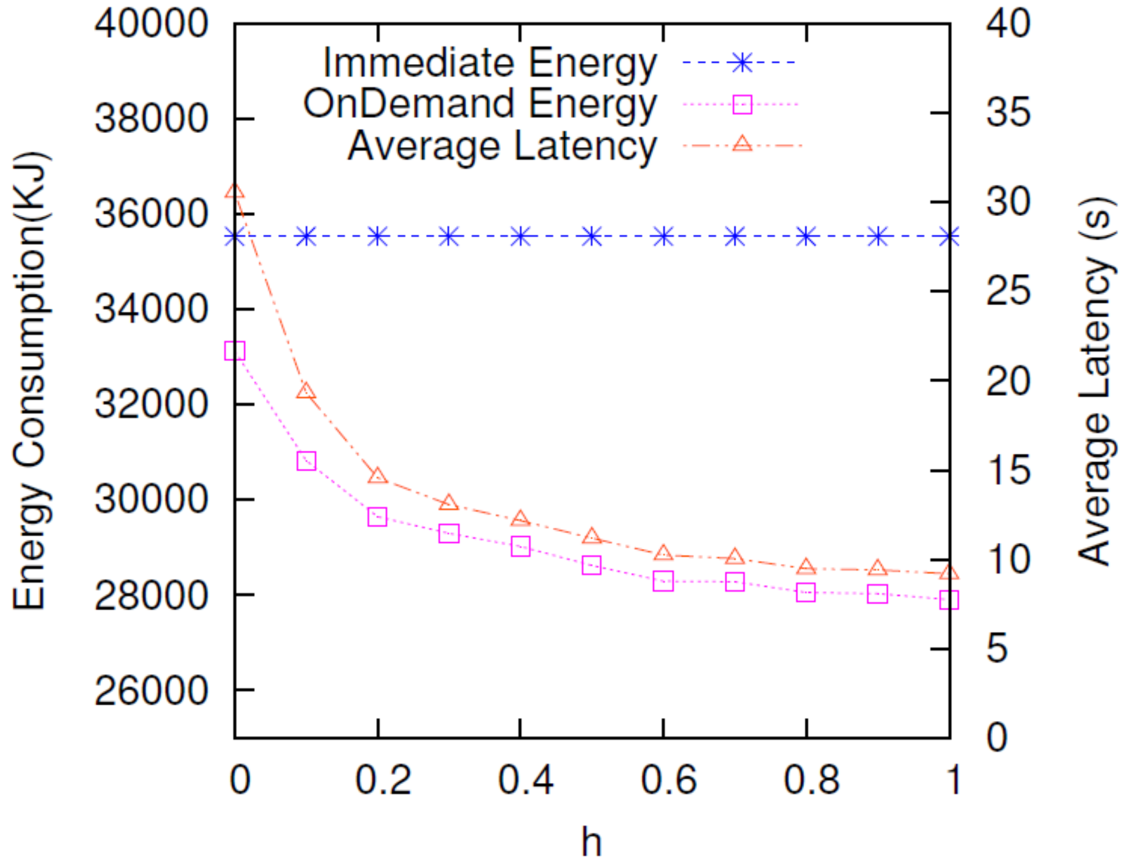
10.16s



Query response latency with N = 2, 000 nodes.

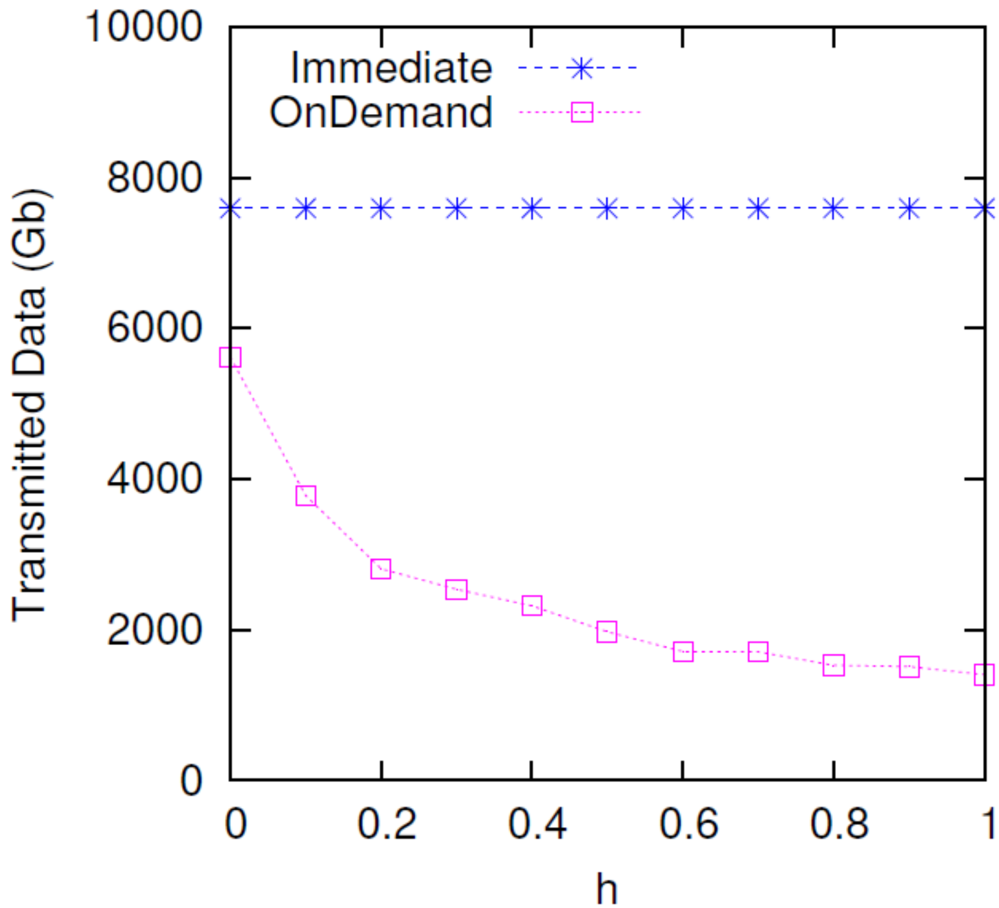
Performance: With Battery Recharging

mobile node density will eventually reach a dynamic equilibrium



Energy consumption and average query response latency with varying query clustering parameter h.

Performance: With Battery Recharging



Total transmitted data size as a function of query clustering parameter h.

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Functional modules

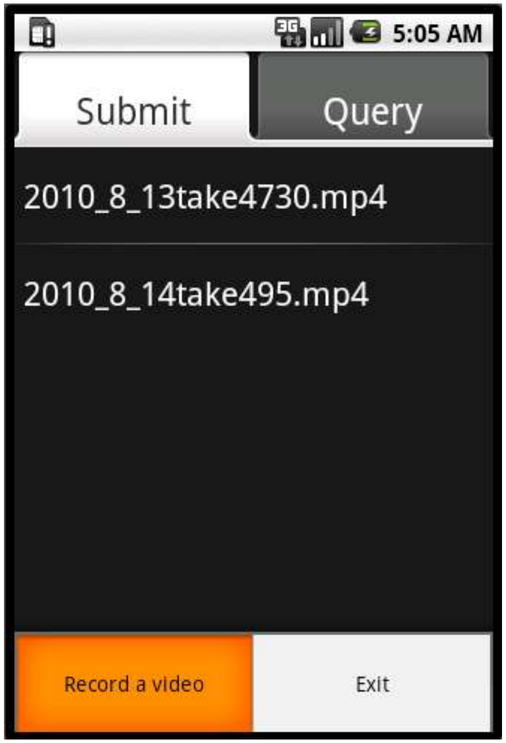
- Video Stream Recorder
- Location Receiver
- Orientation Receiver
- Data Storage and Synchronization Control
- Data Uploader
- Battery Status Monitor

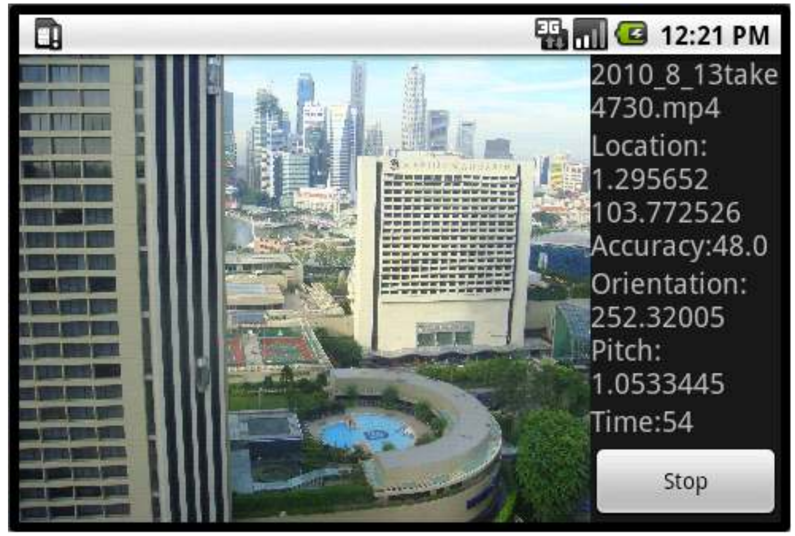
Data format that stores sensor data

JSON (JavaScript Object Notation)


```
{
    "format_version":"0.1",
    "video_id":"a uniquely identifiable video id",
    "owner_properties":{
        "id_type":"google account",
        "id":someone@google.com
    },
    "device_properties":{
        "SIM_id":"an id taken from SIM card",
        "OS":"Android",
        "OS_version":"1.0",
        "firmware_version":"1.0"
    },
    "sensor_data":[
        {
            "location_array_timestamp_lat_long":[
                ["2010-03-18T07:58:41Z",1.29356,103.77],
                ["2010-03-18T07:58:46Z",1.29356,103.78]
            ]
        },
        {
            "sensor_array_timestamp_x_y_z":[
                ["2010-03-18T07:58:41Z",180.00,1.00,1.00],
                ["2010-03-18T07:58:46Z",181.00,1.00,1.00]
            ]
        }
    ]
}
```

Prototype User Interface





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Conclusions

- Capturing video in conjunction with descriptive sensor metadata
- Uploading the sensor information in real-time while transmitting the bulky video data on demand later
- Reduce the transmission of uninteresting videos
- Lower the energy consumption in battery-powered mobile camera nodes

Conclusions

- Present the design and prototype implementation of a mobile video management system
- Demonstrate the energy efficiency of our system with simulations
- Substantially prolong the device usage time, while ensuring low search latency
- Expect this method to be useful for a wide range of novel applications

Thank you!