Urban Sensing Applications

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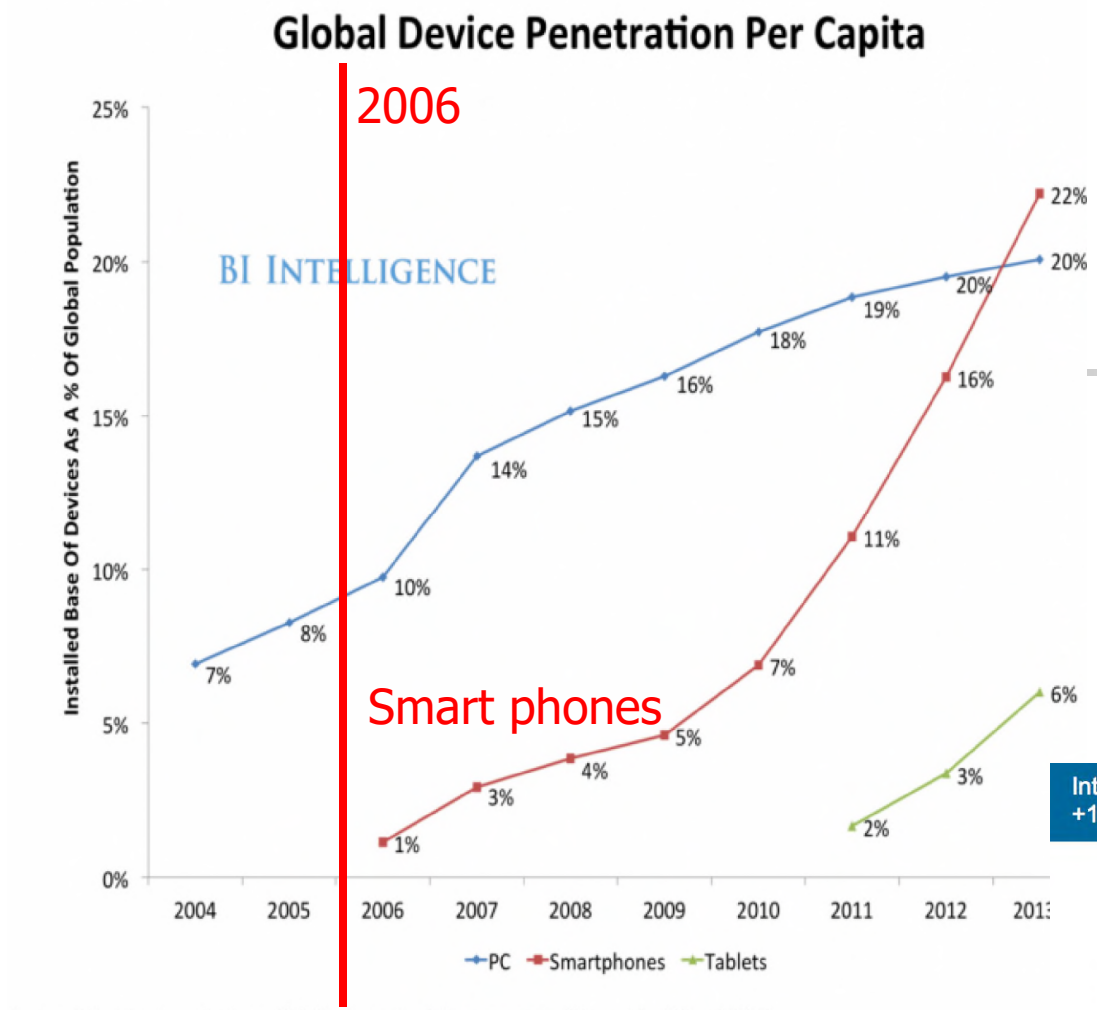
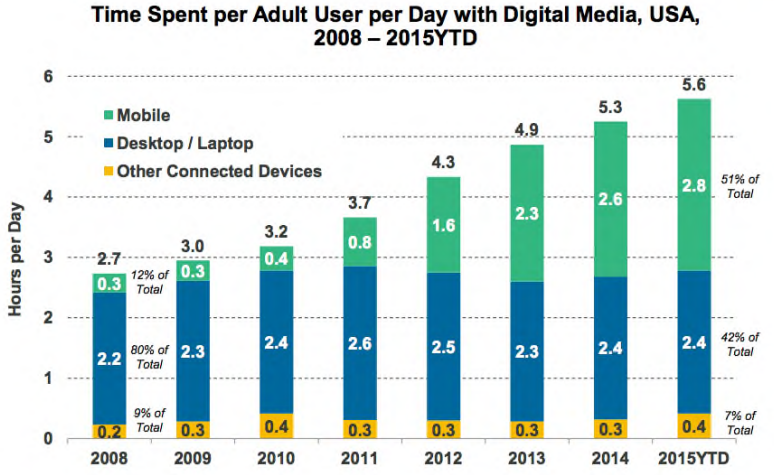
History
Initial Drivers: Smartphones and Connected Vehicles

- J. Burke, D. Estrin, M. Hansen, A. Parker, N. Ramanathan, S. Reddy, M. B. Srivastava. "Participatory sensing," In Proc. World Sensor Web Workshop, ACM Sensys, Boulder, Colorado, October 31, 2006.
- Andrew T. Campbell, Shane B. Eisenman, Nicholas D. Lane, Emiliano Miluzzo, and Ronald A. Peterson, "People-centric Urban Sensing," In Proc. 2nd annual international workshop on Wireless Internet (WICON), 2006.
- Tarek Abdelzaher, Yaw Anokwa, Péter Boda, Jeff Burke, Deborah Estrin, Leonidas Guibas, Aman Kansal, Sam Madden, Jim Reich, "Mobiscopes for Human Spaces," IEEE Pervasive, Vol. 6, No. 2, pp. 20-29, April 2007.
- Raghu Ganti, Fan Ye, and Hui Lei, "Mobile CrowdSensing: Current State and Future Challenges," IEEE Communications Magazine - Special issue on IoT, Vol. 49, No. 11, November 2011.
- Mani Srivastava, Tarek Abdelzaher, Boleslaw K. Szymanski, "Human-centric Sensing," Philosophical Transactions of the Royal Society, special issue on Wireless Sensor Networks, Vol. 370, No. 1958, pp. 176-197, January 2012.
- Dong Wang, Bolek Szymanski, Tarek Abdelzaher, Heng Ji, and Lance Kaplan, "The Age of Social Sensing," IEEE Computer, 2018.

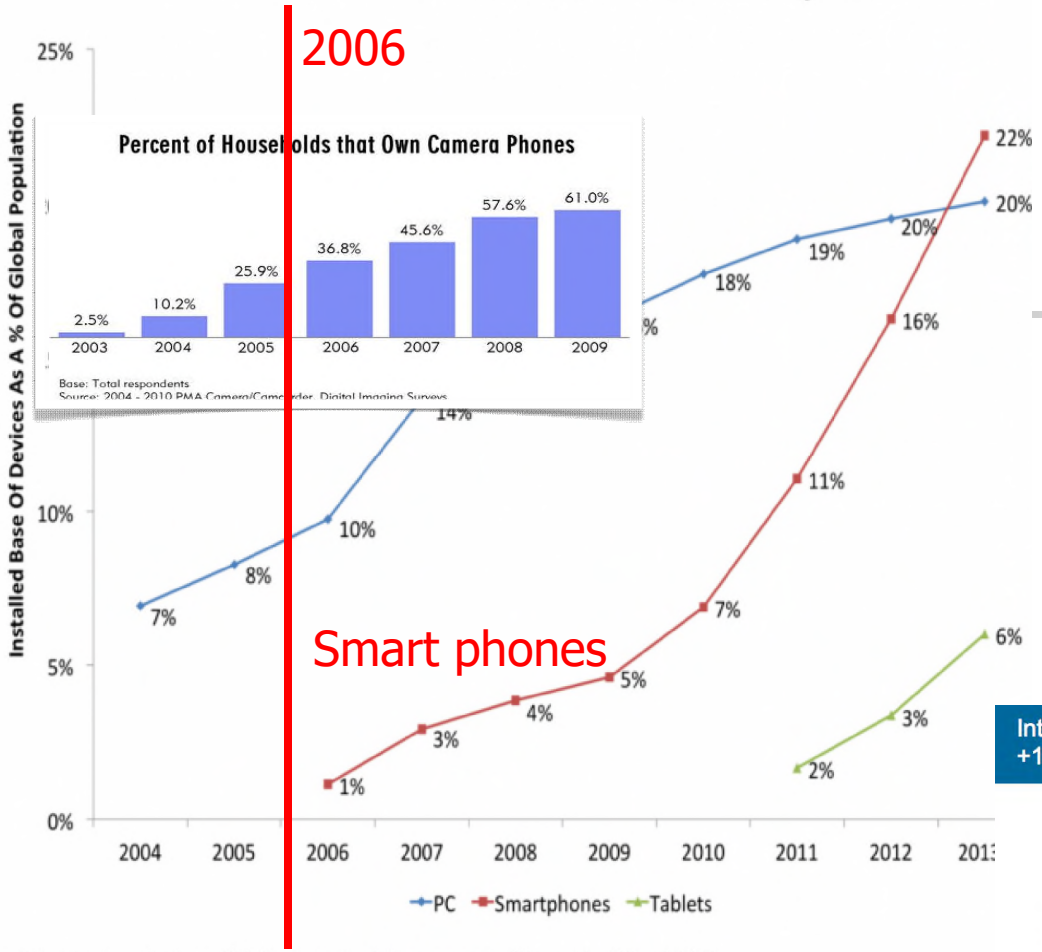


Source: BII estimates, Gartner, IDC, Strategy Analytics, company filings, World Bank 2013

Internet *Usage* (Engagement) Growth Solid
+11% Y/Y = Mobile @ 3 Hours / Day per User vs. <1 Five Years Ago, USA



Global Device Penetration Per Capita



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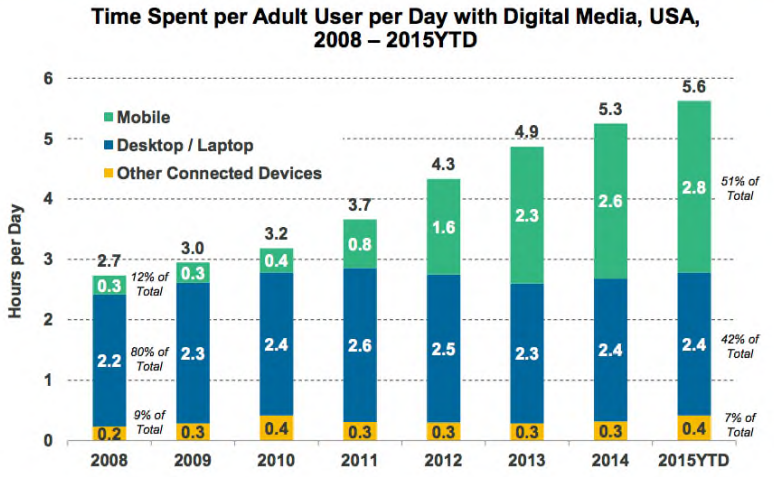


@KPCB Source: eMarketer 9/14 (2008-2010), eMarketer 4/15 (2011-2015). Note: Other connected devices include OTT and game consoles. Mobile includes smartphone and tablet. Usage includes both home and work. Ages 18+; time spent with each medium includes all time spent with that medium, regardless of multitasking.

Sensing Gadgets

- Google Glass

Sensing Gadgets
SmartGlasses in 2018

Vuzix Blade AR

(Augmented Reality)

$1800

Snap Spectacles (upload 10sec video to snapchat/Twitter)

Solos (fitness stats display for cyclists), $500

ODG R7/R8/R9 (Augmented Reality) PokemonGo included, $3K

Personal Sensing Gadgets

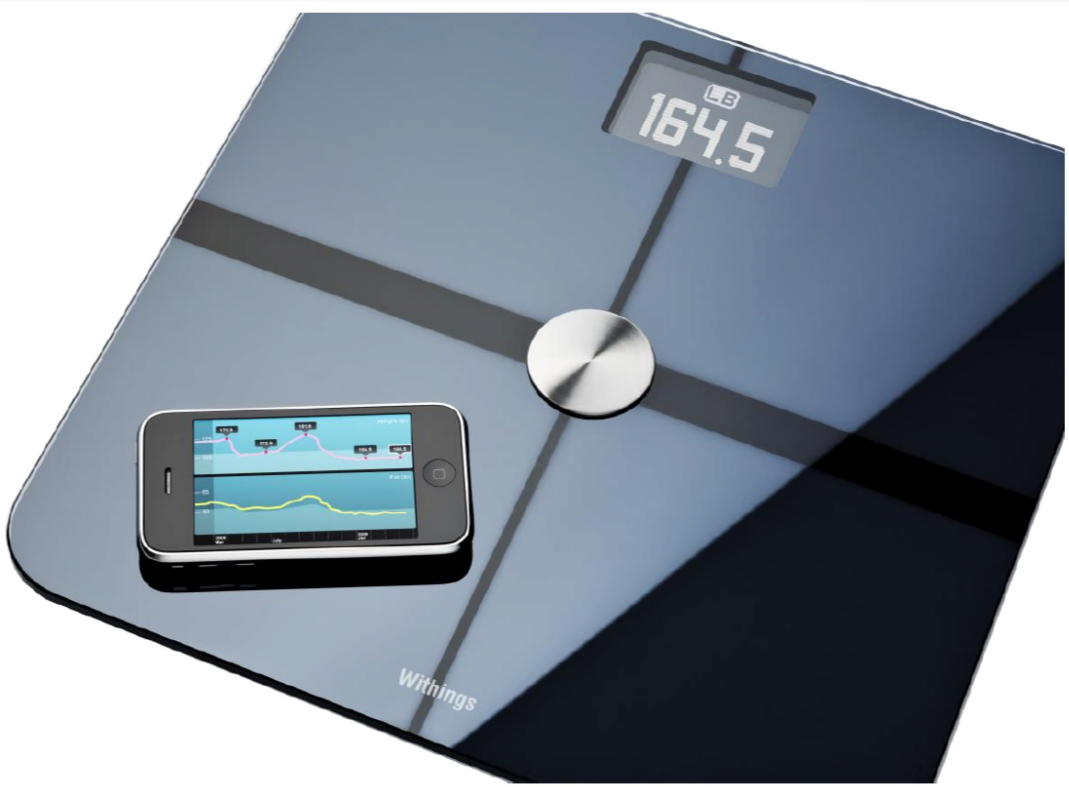
Sleep and activity tracking

Activity tracking earbuds

Sleep and activity tracking

Personal Sensing Gadgets

- Withings (smart scale, etc)



Sensing Gadgets for Cars

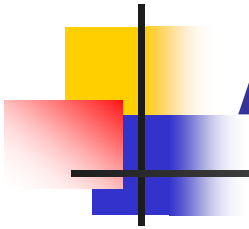
- OBD II

Sensing Gadgets for Things

- RFIDs and tracking (e.g., luggage)

Universal Sensing Gadgets

- Smart Phones



A Note on Projects

- You can propose a device budget of up to $500
  - Make a case for why you need the devices and what you want to do with them
  - We shall order them (if the case is convincing)

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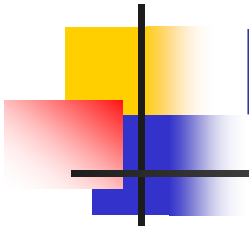

Participatory Sensing

- Architectural elements:
  - Network attested context: location and time
  - Physical context
  - Context resolution control
- Discovery, Naming, Dissemination
- Campaigns

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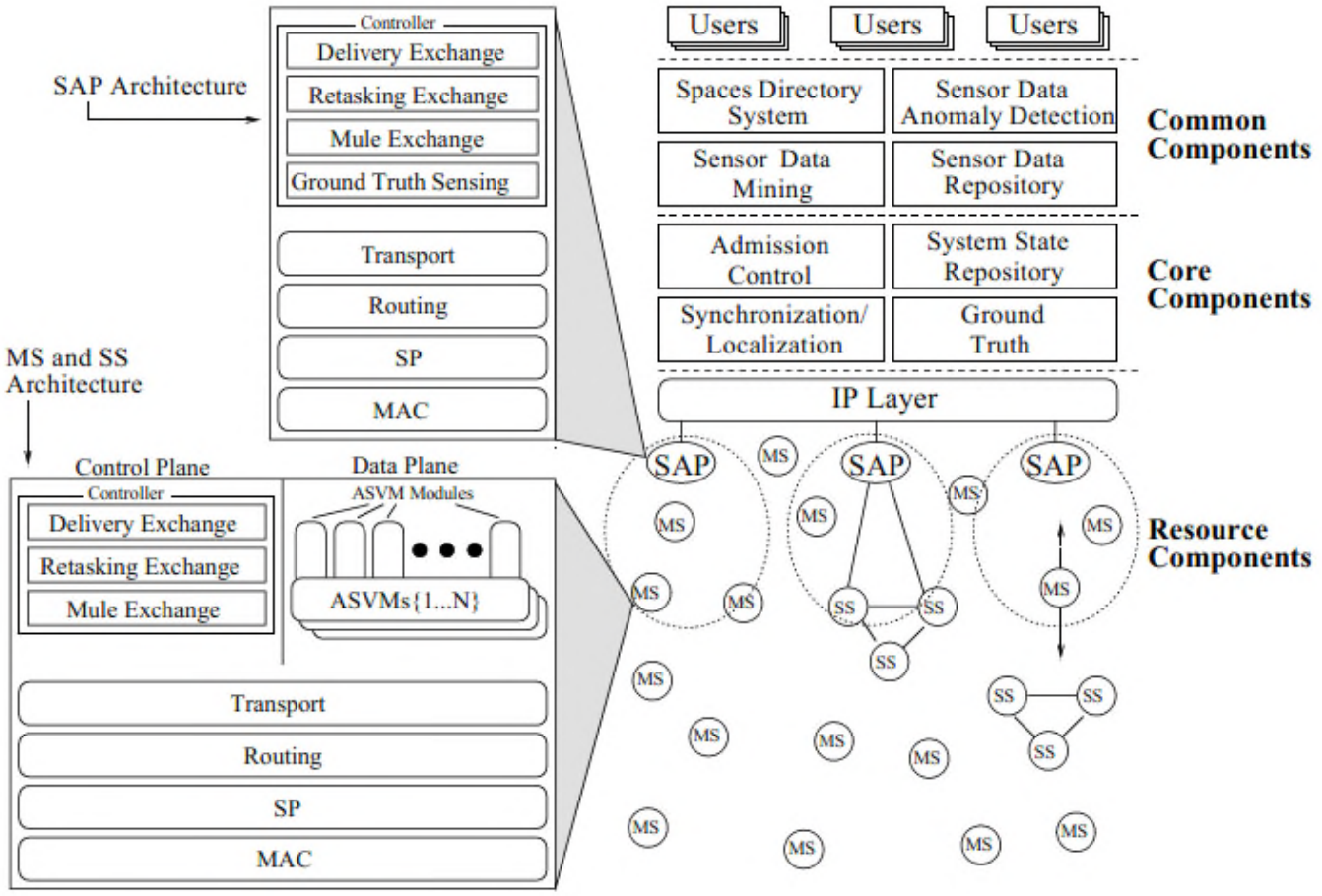
MetroSense



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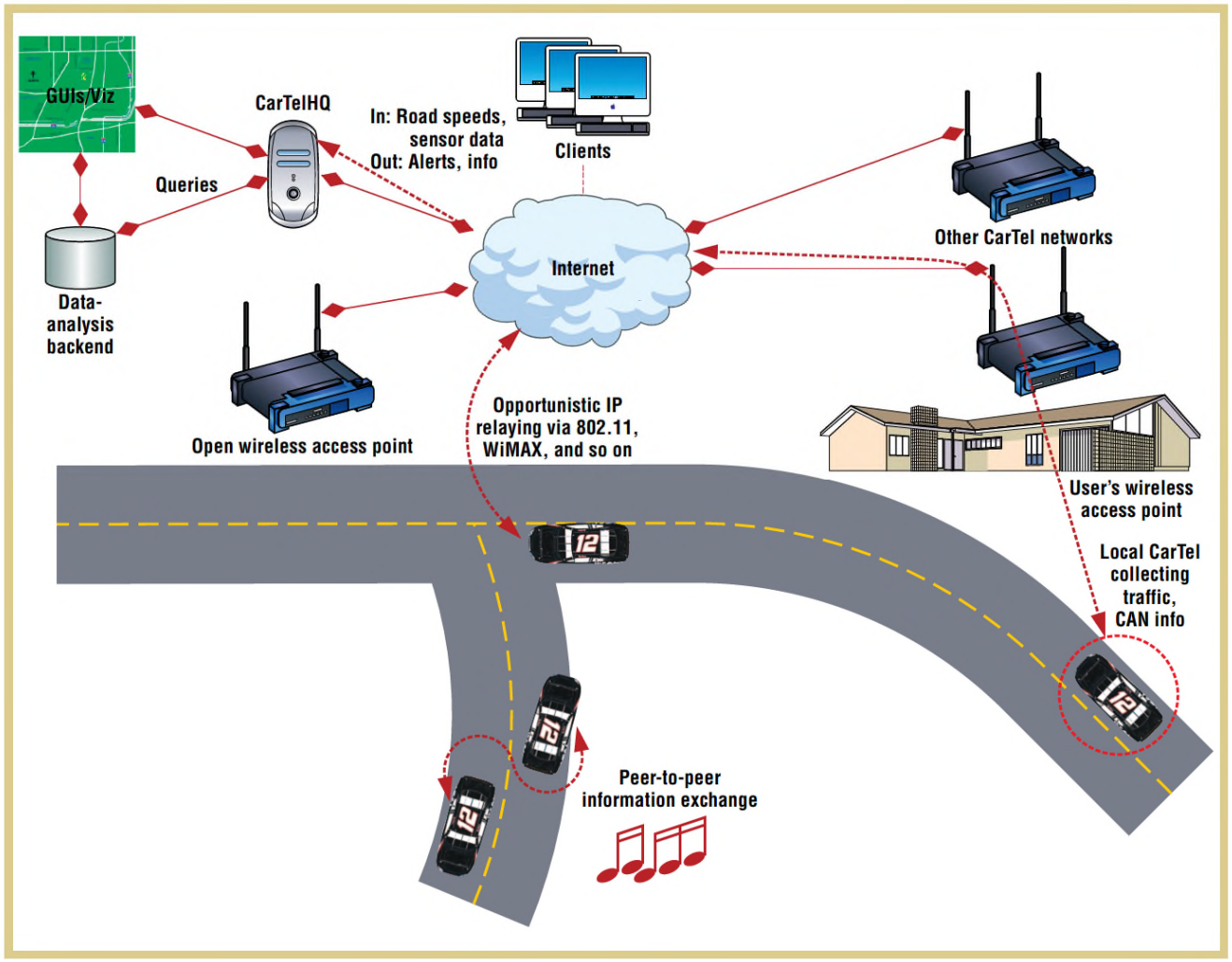
Mobiscopes



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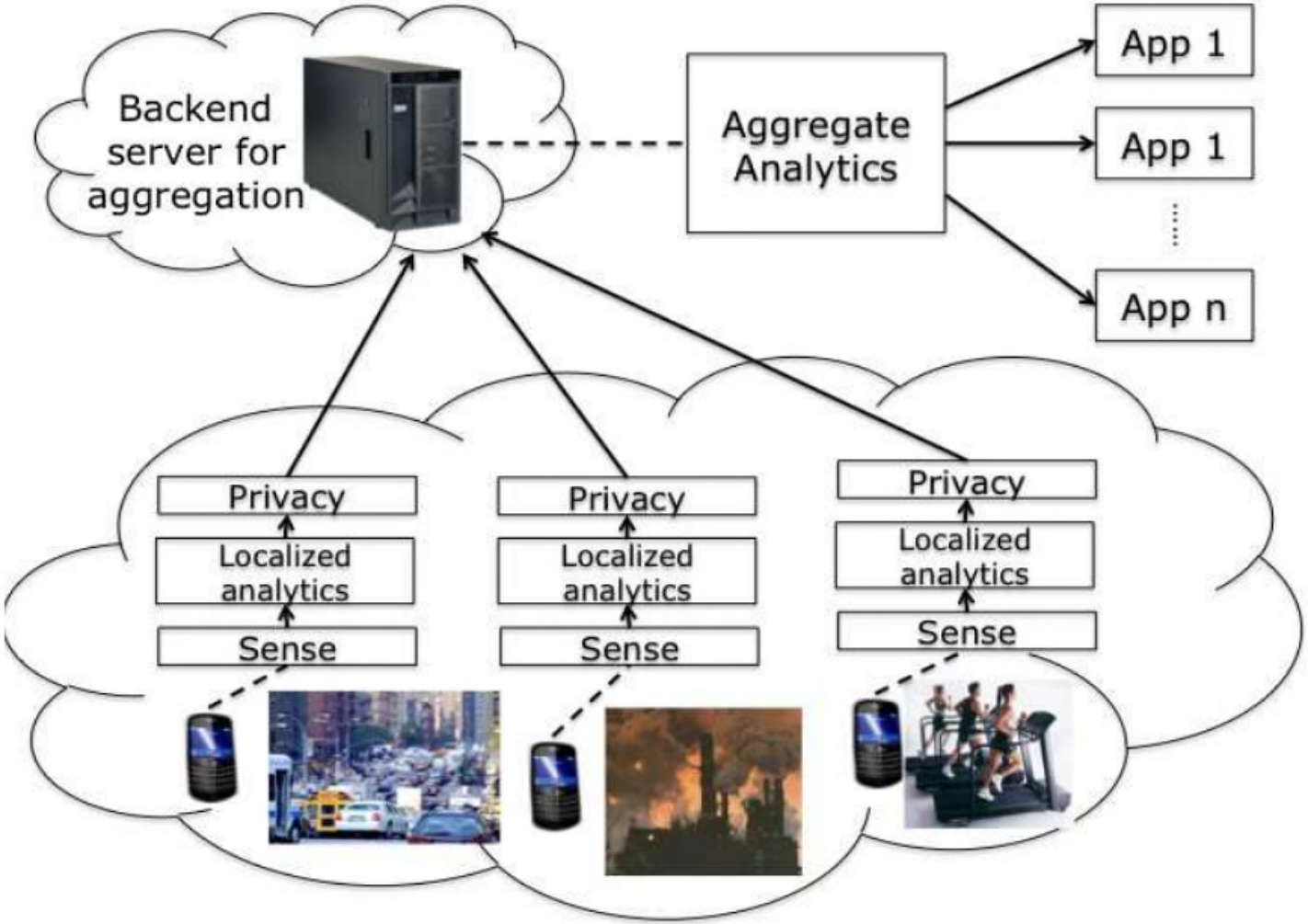
Mobile Crowdsensing



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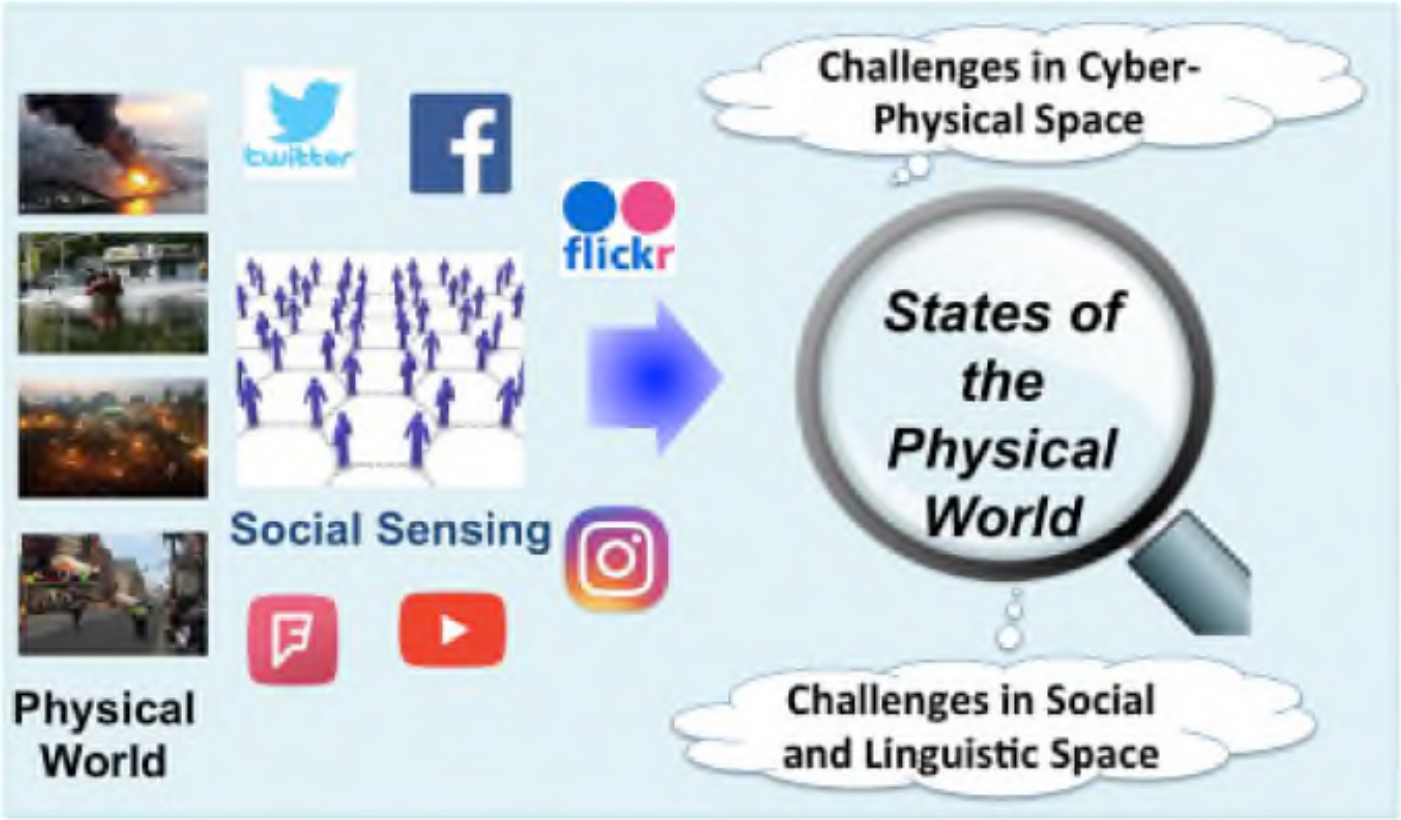
Human-centric Sensing

- Role of humans in the sensing loop?
  - Target, sensing operator, sensor
- Humans as sensing targets
  - Challenge: understand context, manage/save local resources
- Humans as sensing operators
  - Challenge: manage campaigns, recruit, handle spatio-temporal data, build models, handle privacy
- Humans as sensors
  - Challenge: understanding dynamics, assessing trust

- Dong Wang, Bolek Szymanski, Tarek Abdelzaher, Heng Ji, and Lance Kaplan, "The Age of Social Sensing," IEEE Computer, 2018.

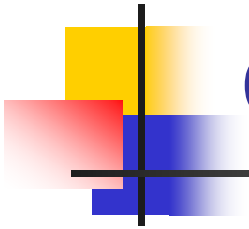
Social Sensing



Social Sensing

- Understanding the signal
- Modeling distortion
- Quantifying fundamental bounds
- Understanding echo-chambers: communities, trust, and polarization
- Fusion of physical and social sensors
- Language challenges

Structure of the (Human-centric) Sensing Landscape



- How is sensing done?
- Who uses the data?
  - Me?
  - My friends?
  - An interest group/the world?
- What is the sensing purpose?
  - Application types
- What does the person do?

Who Uses the Data?

- MetroSense: Where people are the focal point of sensing

Fitness Tracking

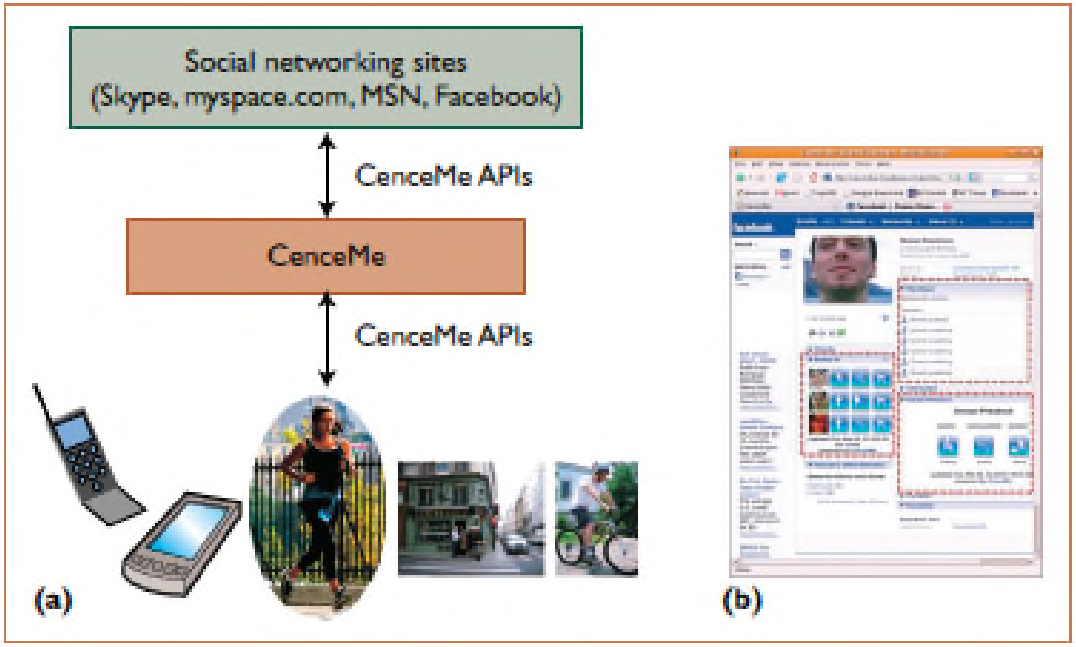
Sleep and activity tracking

Activity tracking earbuds

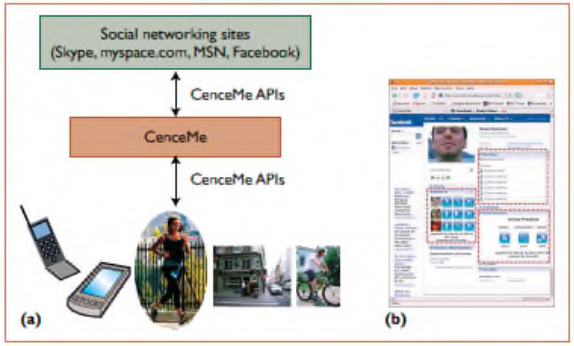
Sleep and activity tracking

CenceMe (2007)

- A Facebook app
- Sensors compute user context (or "sensing presence").
- Context is shared with social circle (e.g., Facebook friends) according to specified privacy policies.



CenceMe

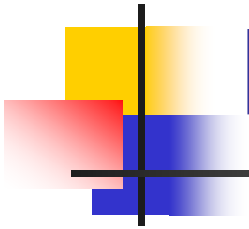


- A Facebook app
- Sensors compute user context
  - *Activities* (sitting, walking, or meeting friends),
  - *Disposition* (happy, sad, or okay)
  - *Locations* (at the gym, coffee shop, or at work) and
  - *Surroundings* (noisy, hot, or bright).
- Context is shared with social circle (e.g., Facebook friends) according to specified privacy policies.

Sharing in Virtual Worlds

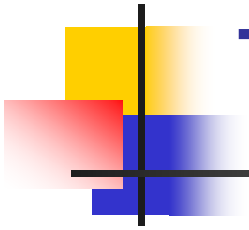
- Integrate second life with sensors in the real world (e.g., on a phone) for various "cyber-physical" games

Sharing in Virtual Worlds



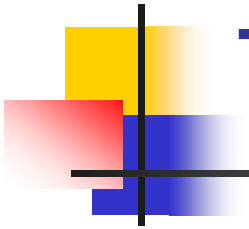
Data for All: Vision

- Exploit mobile devices and dissemination options in the possession of individuals to perform acts of sensing for common interest
- Two competing flavors
  - *Participatory sensing*
  - *Opportunistic sensing*



Two Competing Flavors

- *Participatory sensing:* "the custodian consciously opts to meet an application request out of personal or financial interest".
  - Places demand on the user
  - Offers control
- *Opportunistic sensing*: "custodians configure their devices to let [sensing] applications run (subject to privacy and resource usage restrictions), but they might not be aware which applications are active at any given time"

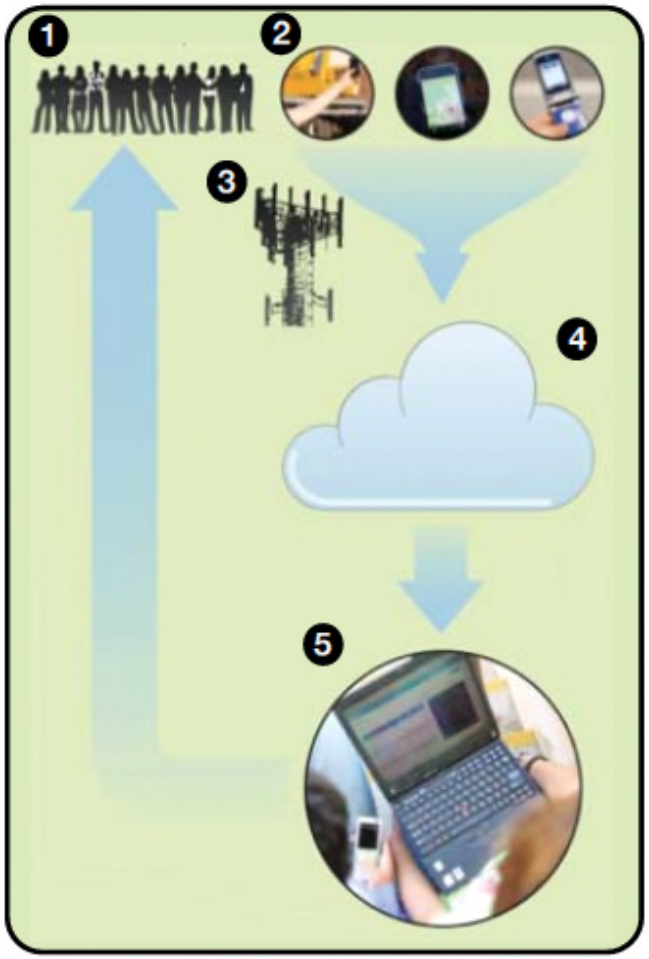


Three Application Types

- Geotagging
- Statistics
- Modeling

Application Types
1. Geo-tagging (participatory)

- Phone-based geo-tagging of events of interest (UCLA)
  - Crowds/pollution on beach
  - Invasive species (weeds)
  - Trucks in residential neighborhoods
  - Drinking fountains



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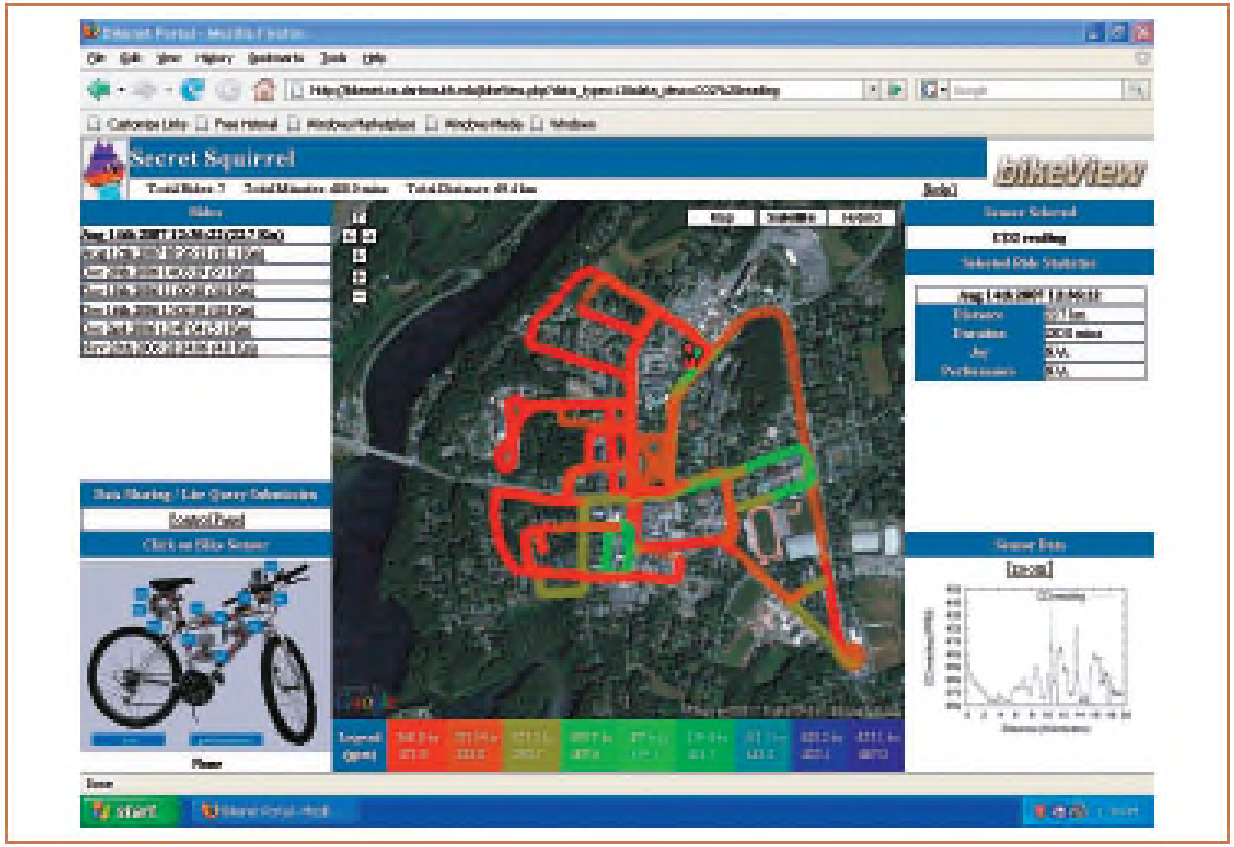
Application Types:
2. Statistics/Mapping (opportunistic)

- Example: BikeNet



Applications:
3. Data Modeling

Green GPS
The fuel efficient option

Saves 6% over shortest path and 13% over fastest path

Subscribers

OBDII-WiFi Adaptor ($50)

+

GPS Phone

Fuel Data + Physical Models

Server

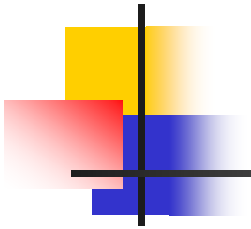
$$F_{engine} = \frac{\Gamma(\omega) G g_k}{r}$$

$$F_{air} = \frac{1}{2} c_d A \rho v^2$$

$$F_{friction} = c_{rr} mg\cos(\theta)$$

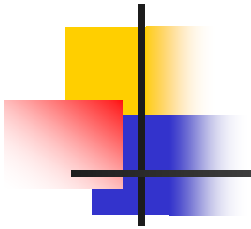
$$F_g^g = mg\sin(\theta)$$

$$F_{car} = F_{engine} - F_{friction} - F_{air} - F_g$$



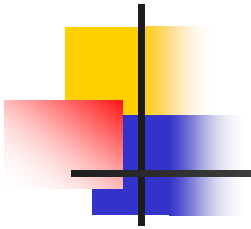
Sensing Challenges

- Humans as Sensing Targets?



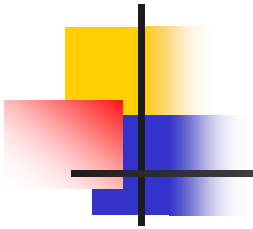
Sensing Challenges

- Humans as Sensing Targets
  - Energy and resource consumption challenges
  - Context inference
    - Who is wearing me?
    - What are they doing?
  - Privacy and data sharing policies
    - What can the application know when?
  - Personal sensor networks
    - My fitbit does not measure my steps when I am pushing a shopping cart. Detect and transfer sensing function to my Nike shoe.



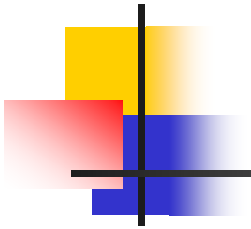
Sensing Challenges

- Humans as Sensor Operators?



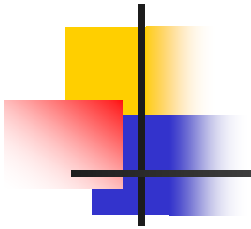
Sensing Challenges

- Humans as Sensor Operators
  - Data collection campaigns: Recruitment and incentive challenges
  - Task assignment challenges (who measures what)
    - Who is where? What's their context?
    - How does the context impact data quality?
    - Who wants what?
    - Patterns of life, mobility prediction, and marginal cost?
    - Assignment for best coverage?
  - Sparse sampling and generalization
  - Privacy and spatio-temporal obfuscation
    - Anonymity is not enough (think GPS traces)
    - Trade-off between privacy and pattern obfuscation effort



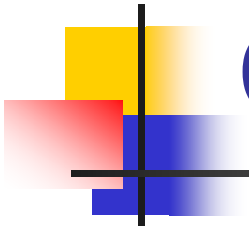
Sensing Challenges

- Humans as Sensors?



Sensing Challenges

- Humans as Sensors
  - What is the noise/perturbation model?
  - How is perturbation correlated? Why is that bad?
  - How to fix it?
- Inferring trust/influence patterns
- Inferring correlated bias
- Data cleaning challenges:
  - Accounting for correlations
  - Accounting for source reliability
  - Accounting for confidence in data
  - Accounting for opportunity to observe
  - Accounting for "chattiness" and silence
  - Accounting for time lapse



Conclusion

- A very rich space is emerging where even the simplest applications (geotagging) lead to interesting research problems. More on that in the rest of the semester…