World Wide Sensor Web

Wearable Personal Instrumentation

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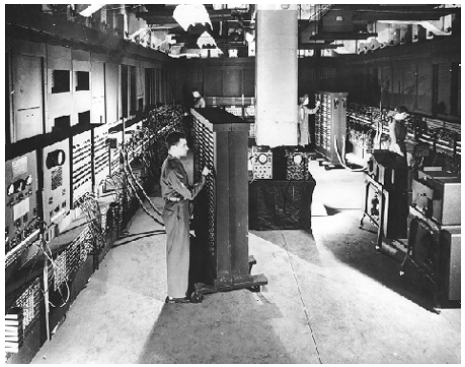
Feasibility of Wearable Personal Instrumentation



Miniaturization of computing devices and sensors => feasibility of embedding computing devices in clothes

Future Embedded Computing Platforms

Future Embedded Computing Platforms

Transparent Personal Instrumentation

A Personal Instrumentation Example

Smart Winter Jacket

A Personal Instrumentation Example

a) Winter Jacket Prototype

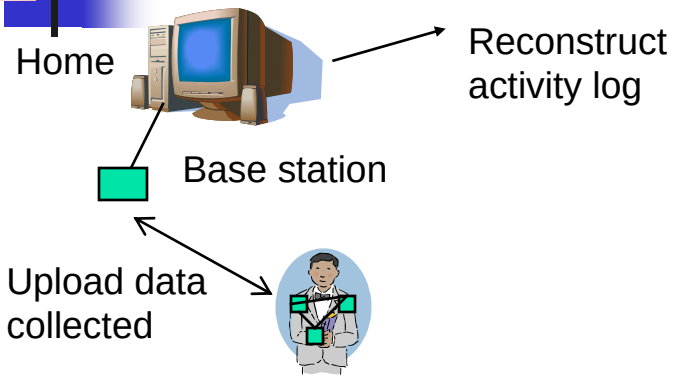
Hardware

Resident Mote

b) Mica z mote

c) MTS310 sensor board

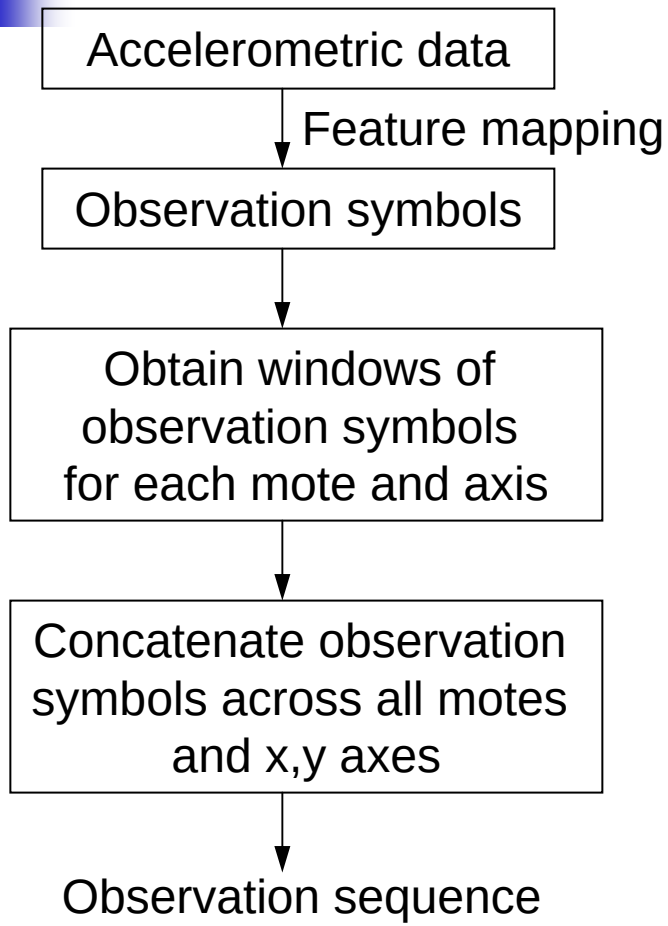
Typical Application scenario



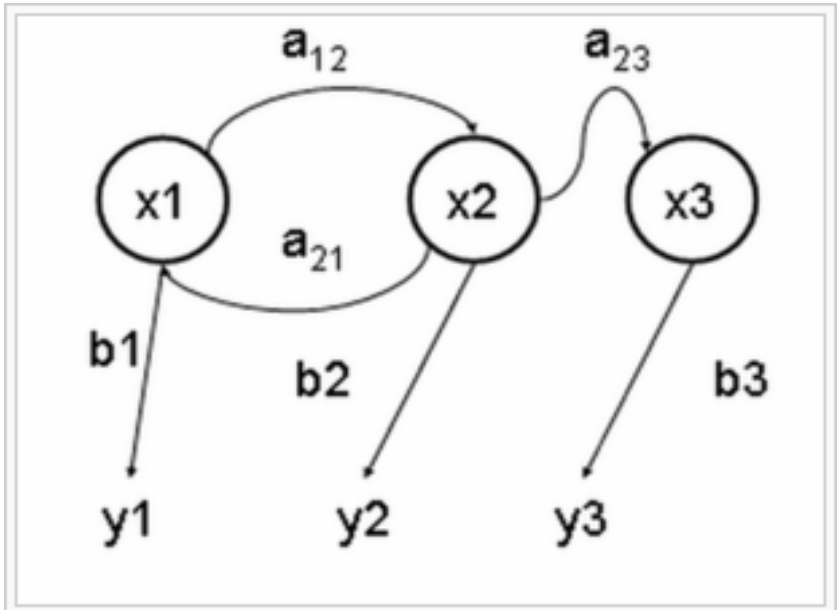
Log activities and location (GPS) remotely.

Mapping using GPS

Classification using HMMs

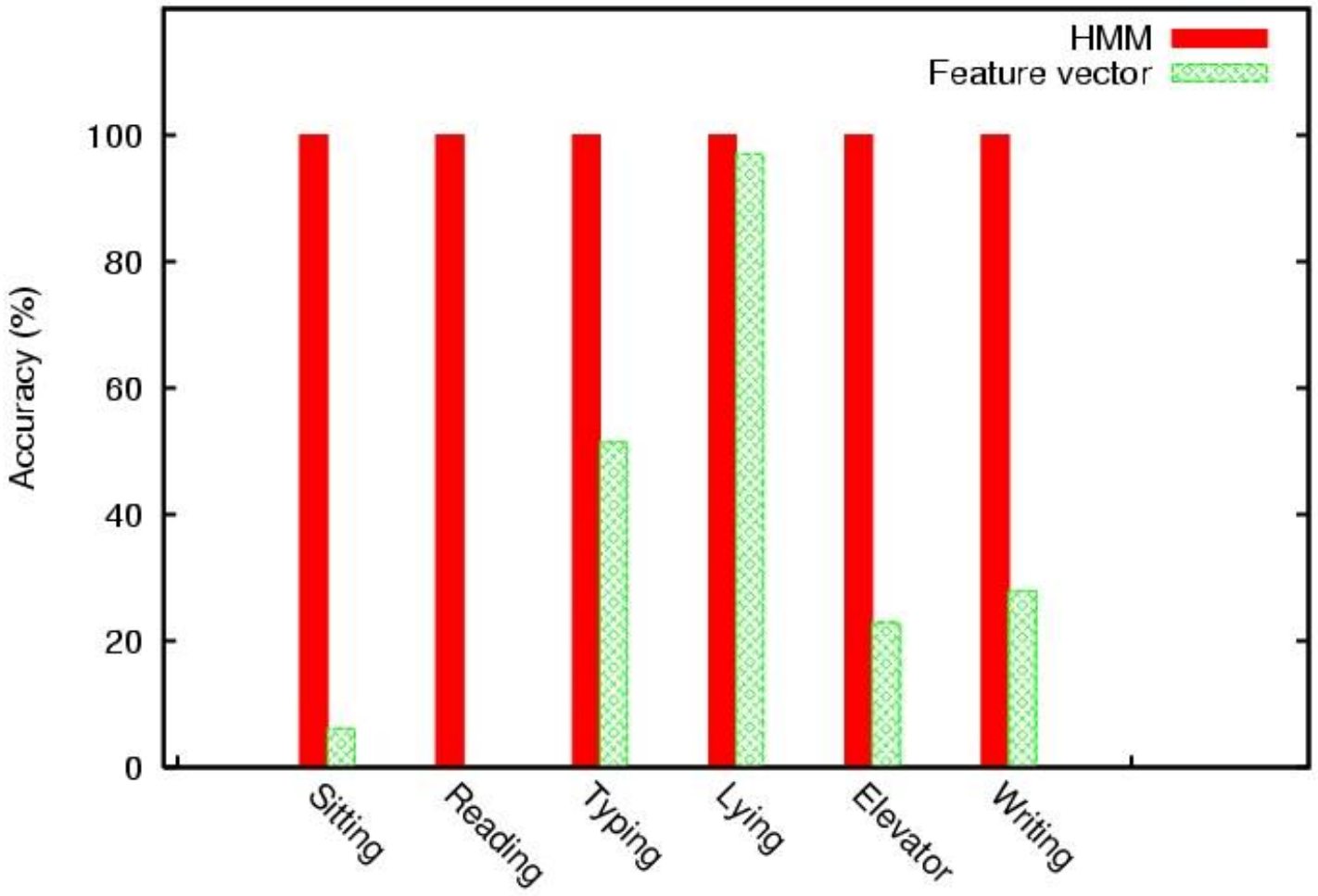


- Hidden states
- Input: Observation

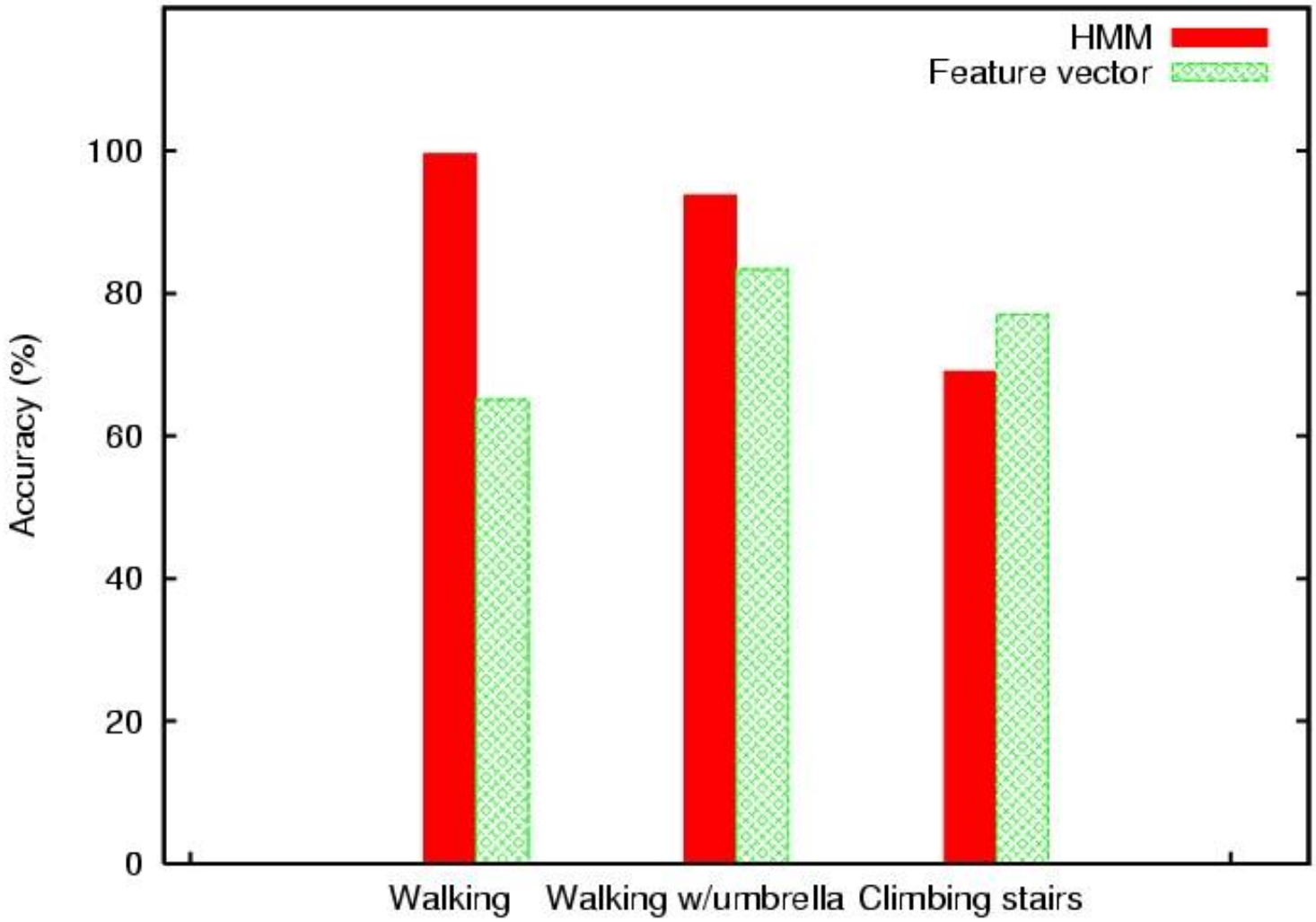


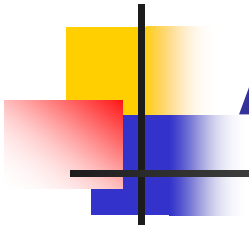
State transitions in a hidden Markov model (example)
x — hidden states
y — observable outputs
a — transition probabilities
b — output probabilities

Static Activity Identification



Dynamic Activity Identification

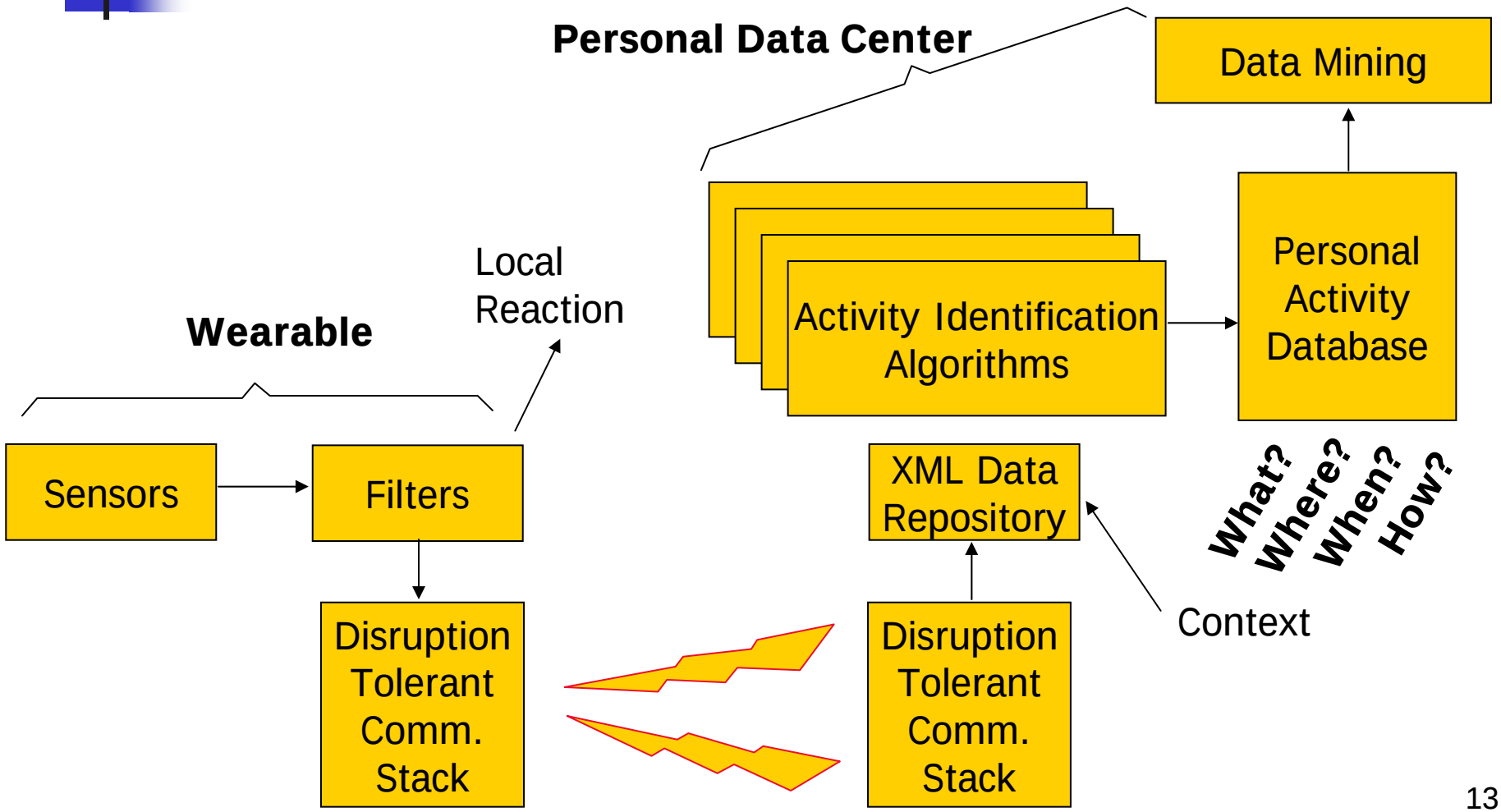




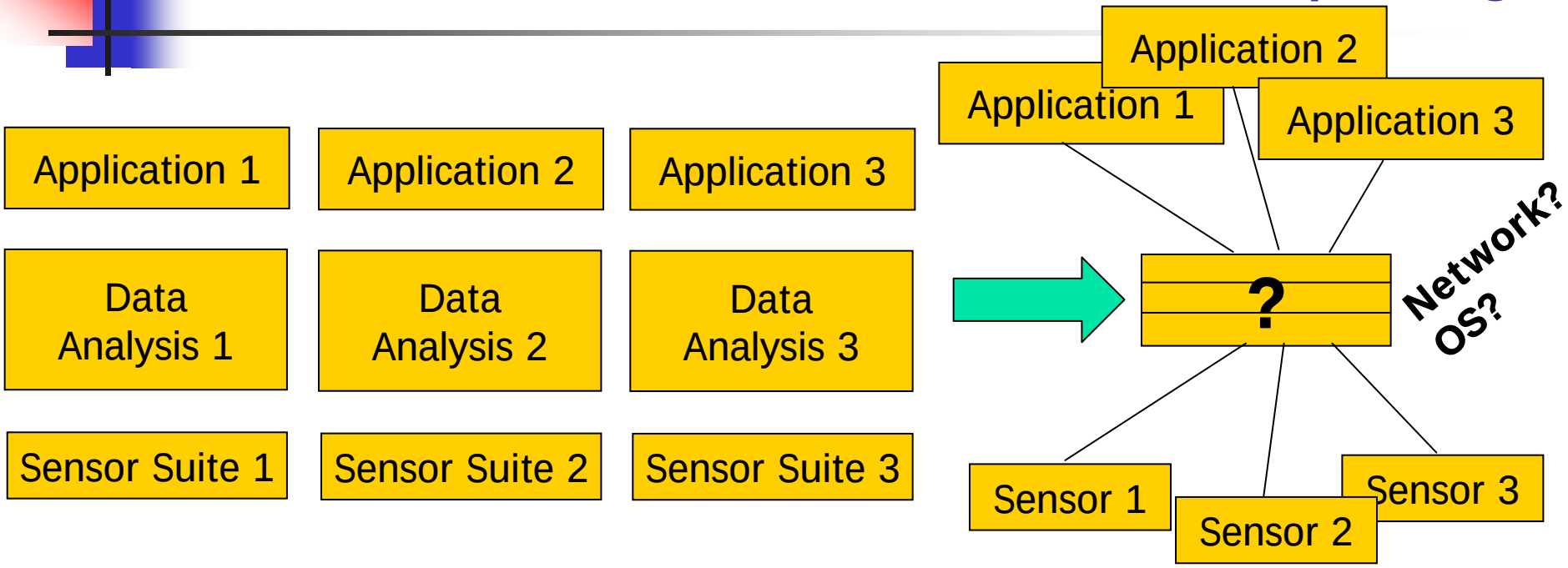
Applications

- Personal
  - Self-browser
  - Remind me services, assisted living
  - Personal trend analysis
- Family
  - Remote window
- Social
  - Special-interest groups
    - Weight watchers (activity/weight correlations)
    - Energy watchers

Challenge 1: Layered Architecture
The "Thin Waist" of Wearable Computing



Challenge 1: Layered Architecture
The "Thin Waist" of Wearable Computing



Specialized architectures

General architecture

Sensor evolvability – introduction of new sensors

Algorithms evolvability – new data interpretation tech.

Applications – Easy installation/devel. of new software

Challenge 2: Resources
Energy

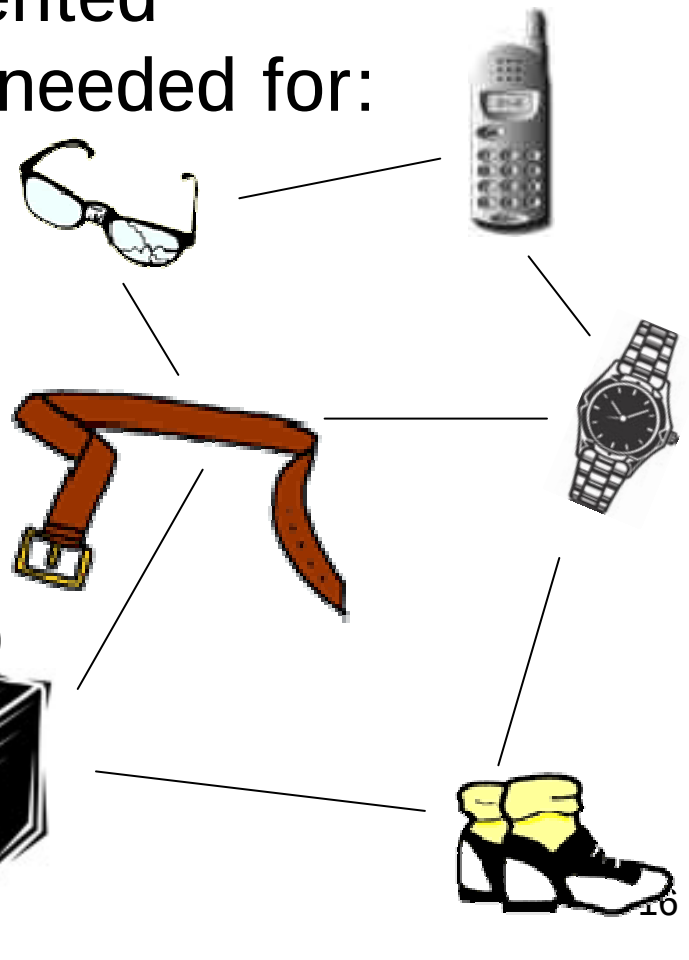
- Sensors such as microphones and accelerometers must operate at a high frequency
- Wearable must last at least one season
- Recharging the wearables?

Scavenging kinetic energy?

Recharging Racks

Challenge 3: Protocols
Wearable Ad Hoc Networks

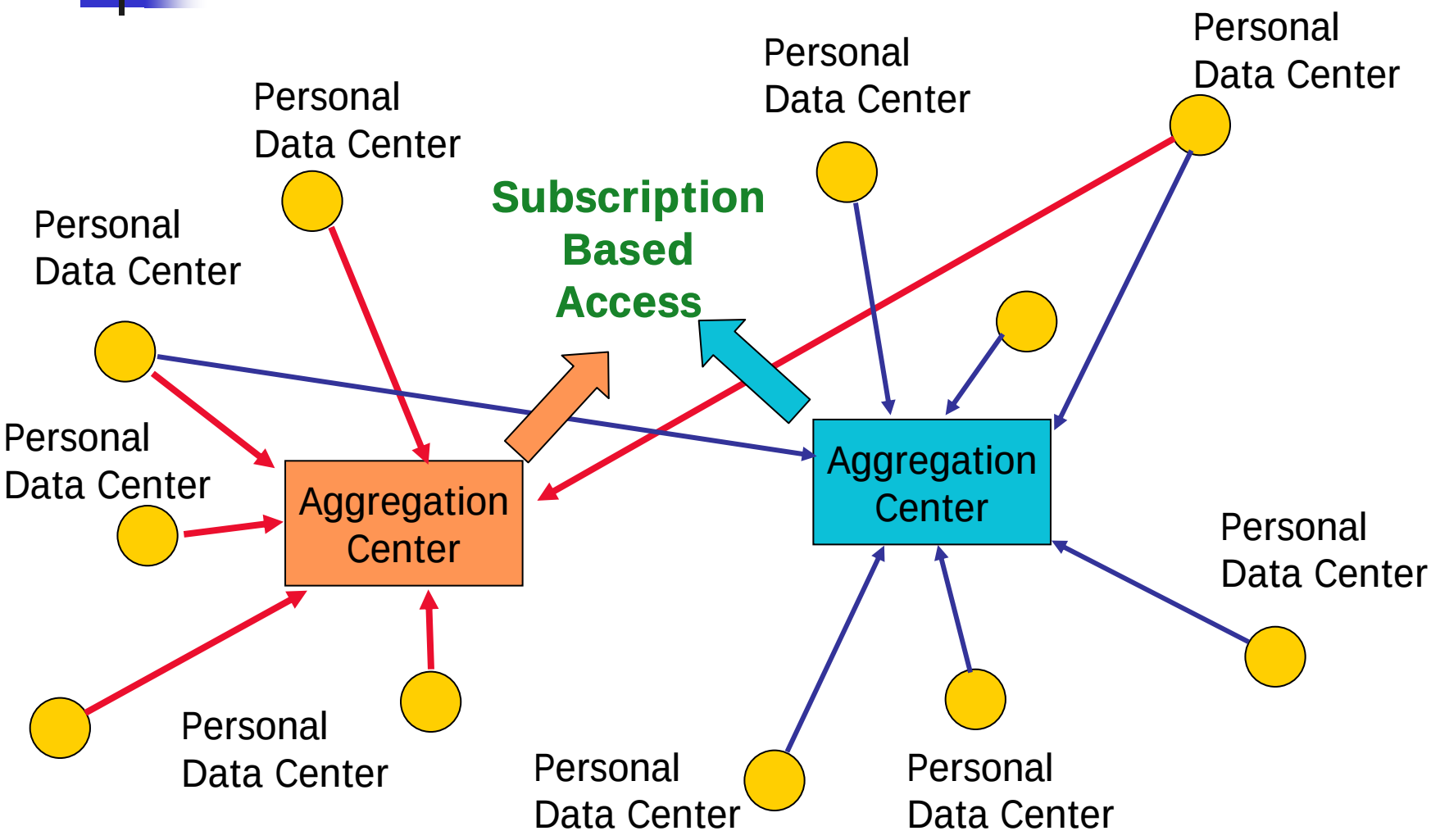
- Multiple items may be instrumented
- "Wear-sensitive" protocols are needed for:
  - Resource discovery
  - Who's wearing me?
  - Time synchronization
  - Cooperative activity identification
  - Opportunistic optimization
  - General-purpose applications
- MAC (reliability, congestion, ...)



Challenge 4: Privacy
A Web of Special Interest Group Applications

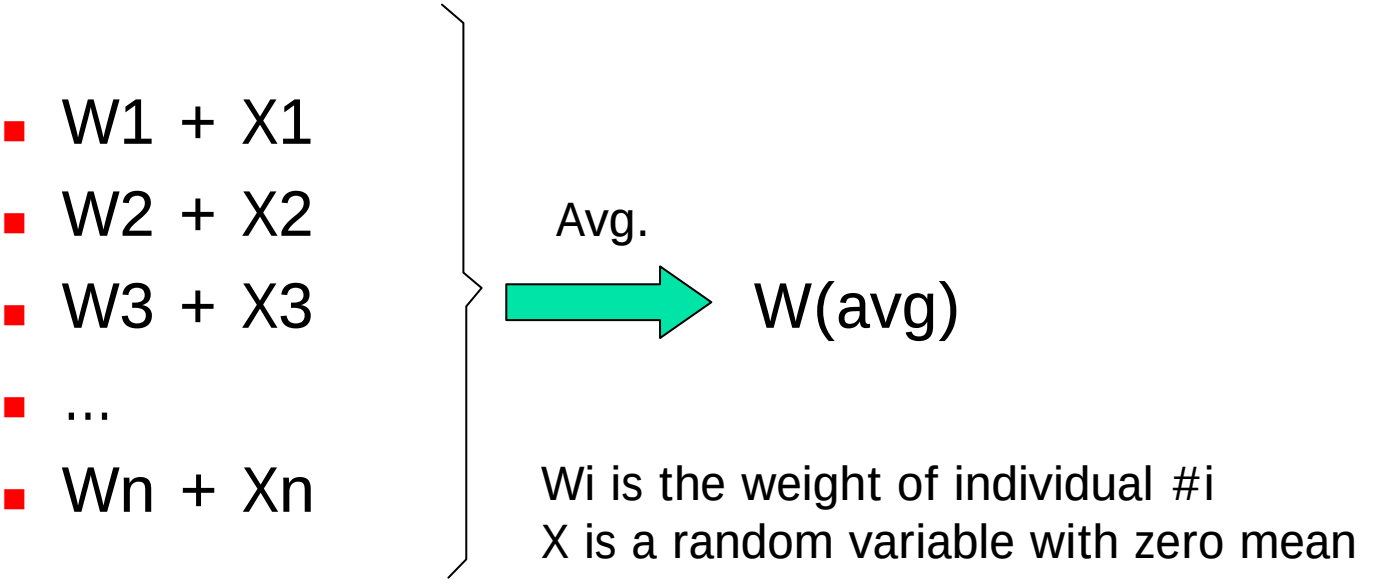
- Queries over special interest groups:
  - What's the average weight loss of individuals on diet X as a function of time?
  - What's the average electric energy consumption of individuals at location Y?
  - How many gallons of water are used annually on watering lawns in my neighborhood?

The Web of Personal Data



Privacy-Preserving Aggregation

- Problem: Aggregate statistics without disclosing private data
- Example: average weight of special interest group Z (without disclosing individual weights?)

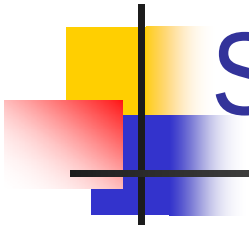


Privacy-Preserving Aggregation

- Problem: How much information is released? Really?
- Example: Privacy of repeated measurements
  - W1(t1) + X11, W1(t2) + X12, ..., W1(tm) + X1m
  - W2(t1) + X21, W1(t2) + X22, ..., W1(tm) + X2m
  - W3(t1) + X31, W1(t2) + X22, ..., W1(tm) + X3m
  - ...
  - Wn(t1) + Xn1, W1(t2) + Xn2, ..., W1(tm) + Xnm

Privacy-Preserving Aggregation

- Example: average weight *trend* of special interest group Z.
  - W1(t1) + X11 + Y1, W1(t2) + X12 + Y1, ..., W1(tm) + X1m + Y1
  - W2(t1) + X21 + Y2, W1(t2) + X22 + Y2, ..., W1(tm) + X2m + Y2
  - W3(t1) + X31 + Y3, W1(t2) + X22 + Y3, ..., W1(tm) + X3m + Y3
  - ...
  - Wn(t1) + Xn1 + Yn, W1(t2) + Xn2 + Yn, ..., W1(tm) + Xnm + Yn



Summary

- A layered software architecture for wearables
- Solving the energy problem
- A suite of “wear-sensitive” protocols
- Privacy-preserving statistics for the sensor web