KNOWME: Exploring the Role of Mobile Devices in Health Care

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Computing in 2020

- **Computing 2020: Yet another paradigm shift**
  - ***Interfacing computing with physical world***
    - ***societal challenges: Health, Infrastructure Efficiency…..***
- **Vision enabled by three layers of computing**
  - ***On Body Computing Devices***
    - ***Environmental and body sensors, mobile devices***
  - ***Cloud Network***
  - ***Datacenters***
    - ***Resource to synthesize useful info from volumes of data***

Mobile Social Networks

- **Enabled by advancing capabilities of mobile devices**
  - ***Innumerable sensors, reliable and relatively low cost communication***
- **Features of this class of applications**
  - ***Each user in a social group contributes their knowledge about their surrounding environments***
  - ***The collective knowledge can be exploited by the community members for personal or social benefit***

Body Sensing and Processing Systems

Enabling new directions for evidence driven health care

- **Efficient, Just in time information and intervention possibility**
- **Can help motivate, and facilitate self awareness**
- **Data from real life conditions, not just lab tests**
- **New research capabilities**
- **An interdisciplinary enterprise: medicine, public health, technology, policy and society**

KNOWME for Obesity

- **Pediatric Obesity and Metabolic Health: A compelling use domain**
  - ***33.6% of children above normal weight***
  - ***Overall increase of 5.4% from 2000 to 2004***
  - ***Only 35.8% of HS Students meet suggested daily physical activity rate***
  - ***Estimated Annual Pediatric Obesity Costs***
    - ***$14B, US [cdc.gov], £3.3B, UK [www.nao.org.uk] and between 3.58%-8.73% of GNP inChina, 2000-05***

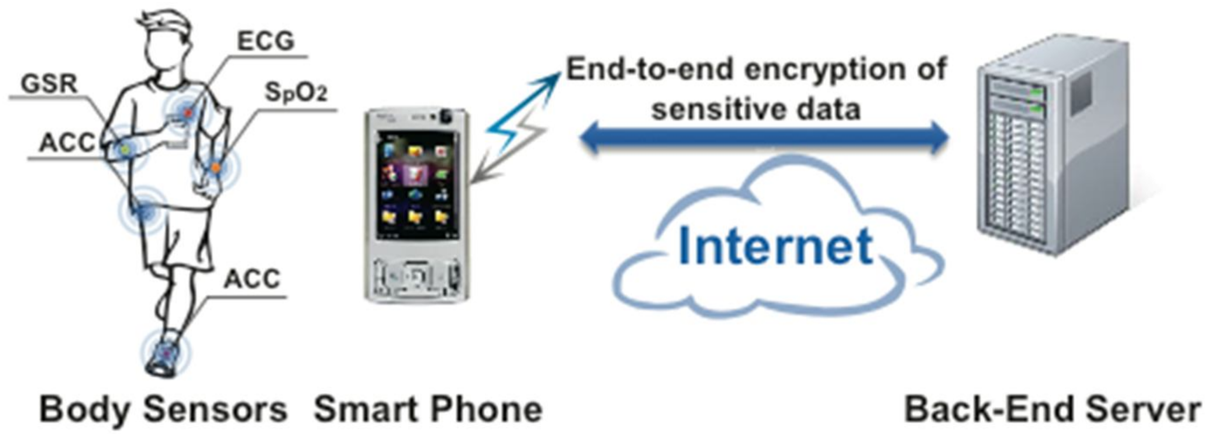
Ogden et al, JAMA, 2006; YRBS, 2005; Popkin, 2006
Metz Spruijt 2009

KNOWME

- **Wireless Body Area Networks (WBANs)**
  - ***An incarnation of people-centric sensing***
- **KNOWME WBAN**
  - ***Integrates external body sensors with mobile phone***
  - ***Measures bio-sensor signals continuously and in real time***
  - ***Classification algorithms to detect user states***
    - ***Simple classification on phone***
    - ***Complex classification on backend***
  - ***Data transmitted to backend for classification***

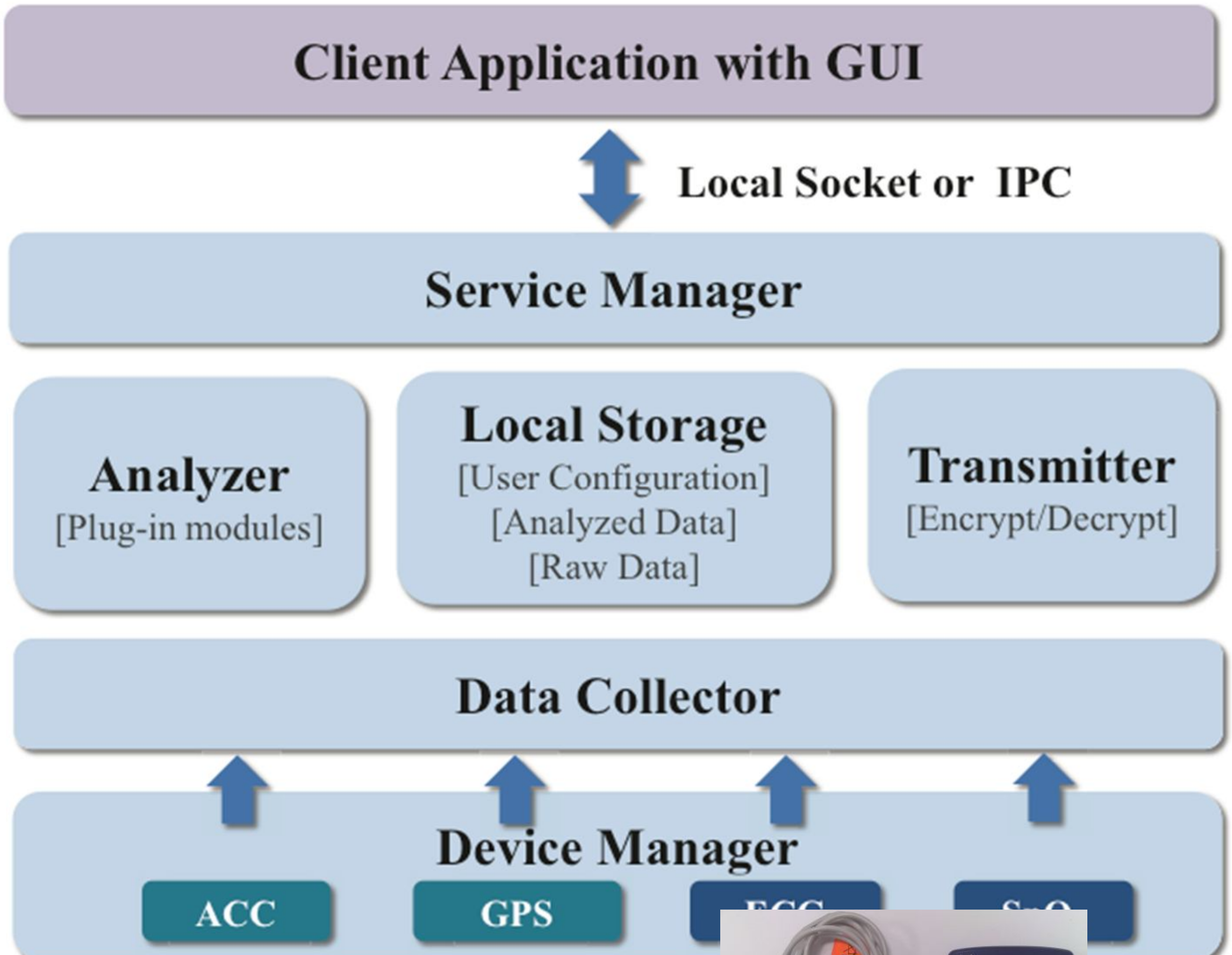
KNOWME Infrastructure

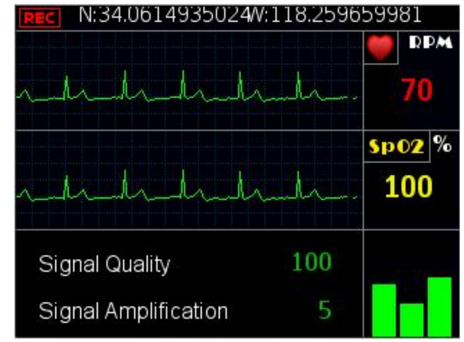
- **Combine health sensors with mobile (N95)**
  - ***Metabolic data: ECG, ACC, OXI***
  - ***Emotional data: GSR***
  - ***User initiated data: SMS, speech notes, images/videos, Tweet Feeds***
  - ***Location data: GPS***

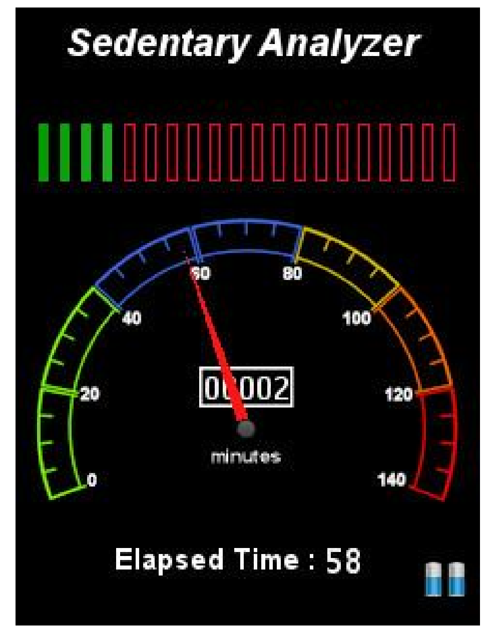


KNOWME Mobile Client: Software Overview

Client Software role : Sensor, aggregator, analyzer, transmitter & on body compute.







Free living studies for 9 months with ~0 crashes!

KNOWME for New Domains

- Few domains of interest: chronic obstructive pulmonary disease (COPD), diabetes, post injury rehabilitation
- COPD: Integrating new sensors for measuring air quality, spirometry (peak flow), ... into KNOWME-like infrastructure
- Run new class classification and correlation algorithms on the mobile phone for auto-detection of disease severity
- Pinning the context with the disease

Mobile as a Center Piece

- **As we bring KNOWME to new domains mobile is the center piece**
  - ***Data aggregation, data analysis, automatic user feedback, data communication***
- **Interdisciplinary research**
  - ***Work with KECK medical team to understand the domain and apply existing standards for data collection***
  - ***Work with signal processing and communication researchers to analyze signals***
  - ***Build new interfaces to improve mobile phone's usability as a medical monitoring device***

Challenges on Mobile Device Front

- **Mobile devices are battery limited**
  - ***Cannot consume too much energy for analysis and sensing***
- **Health monitoring cannot impact user's ability to interact with the device for other purposes**
  - ***Reduce monitoring demands in terms of computation and communication***
- **User friendly application designs**
  - ***Understanding societal demands and change interfaces***
- **Integration of monitoring into social networks**
  - ***Particularly useful for positive reinforcement, interaction with domain-specific support groups***
- **Dealing with privacy**

Lessons From Free Living Trials

- **Application robustness is key to successful WBAN usage**
  - ***End user compliance depends on robustness and ease of use***
- **Energy efficiency must be dealt with in all aspects of the WBAN design**
  - ***Choice of programming language to sensor sampling***
  - ***Energy efficiency plays major role in robustness***
- **Finally, all effort must be transparent to the user**
  - ***User does not care about what is under the hood***

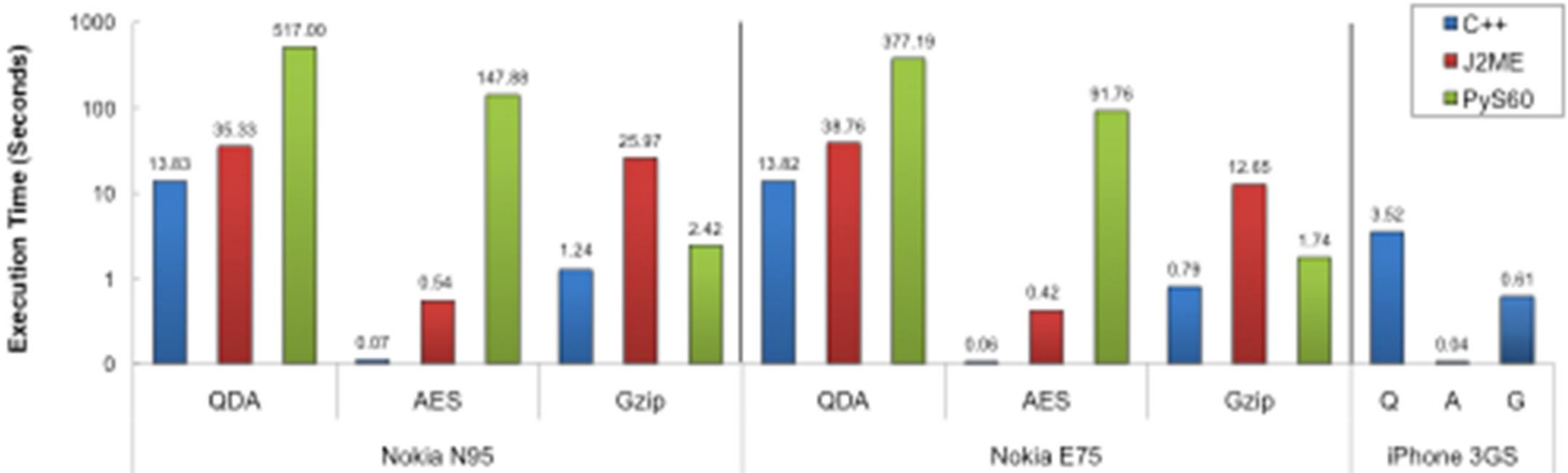
- **Some data generated from KNOWME experiments**
  - ***Focused on energy efficiency issues in mobile phone***
  - ***Solutions currently being developed to tackle this problem***

BACKUP SLIDES FOR FURTHER INFORMATION

Good Choices and Bad Choices

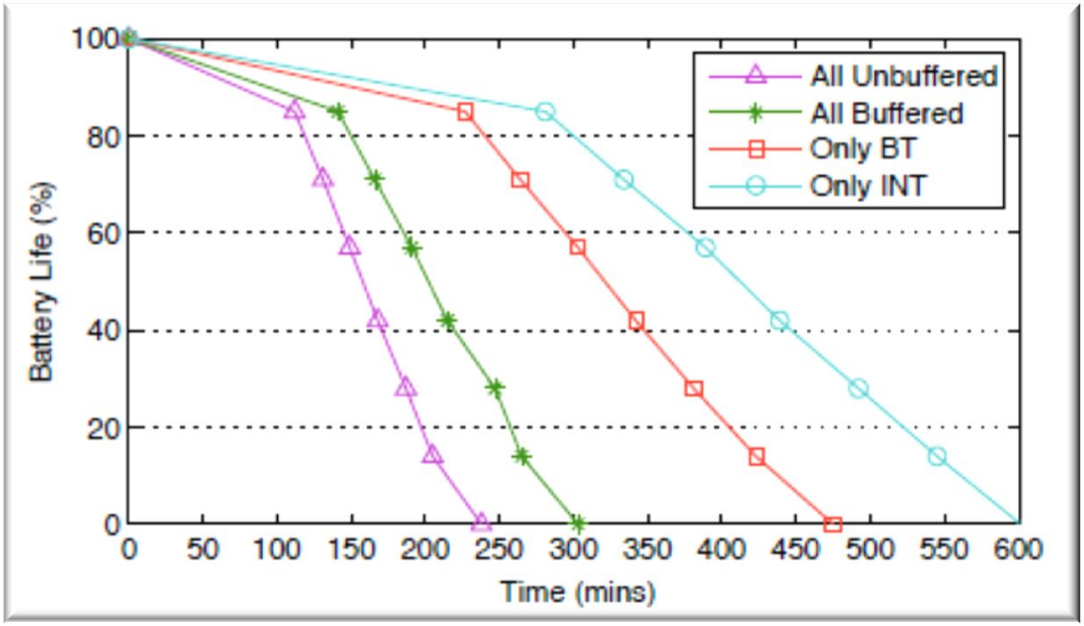
- **Many choices at each WBAN design stage**
  - ***Initial Dev: Efficiency vs. programming simplicity***
  - ***Sense: Sampling rate vs. accuracy***
  - ***Xmit: Signal quality, ZIP & encryption***
  - ***Local vs. remote compute***
- **Each choice has dramatic impact on power consumption**
- **Designer has little knowledge of the energy impact of their choice**
- **Energy impact varies dynamically**
  - ***Signal quality for data transmission, Indoor/Outdoor GPS, Compression factors***

Programming Simplicity vs. Efficiency



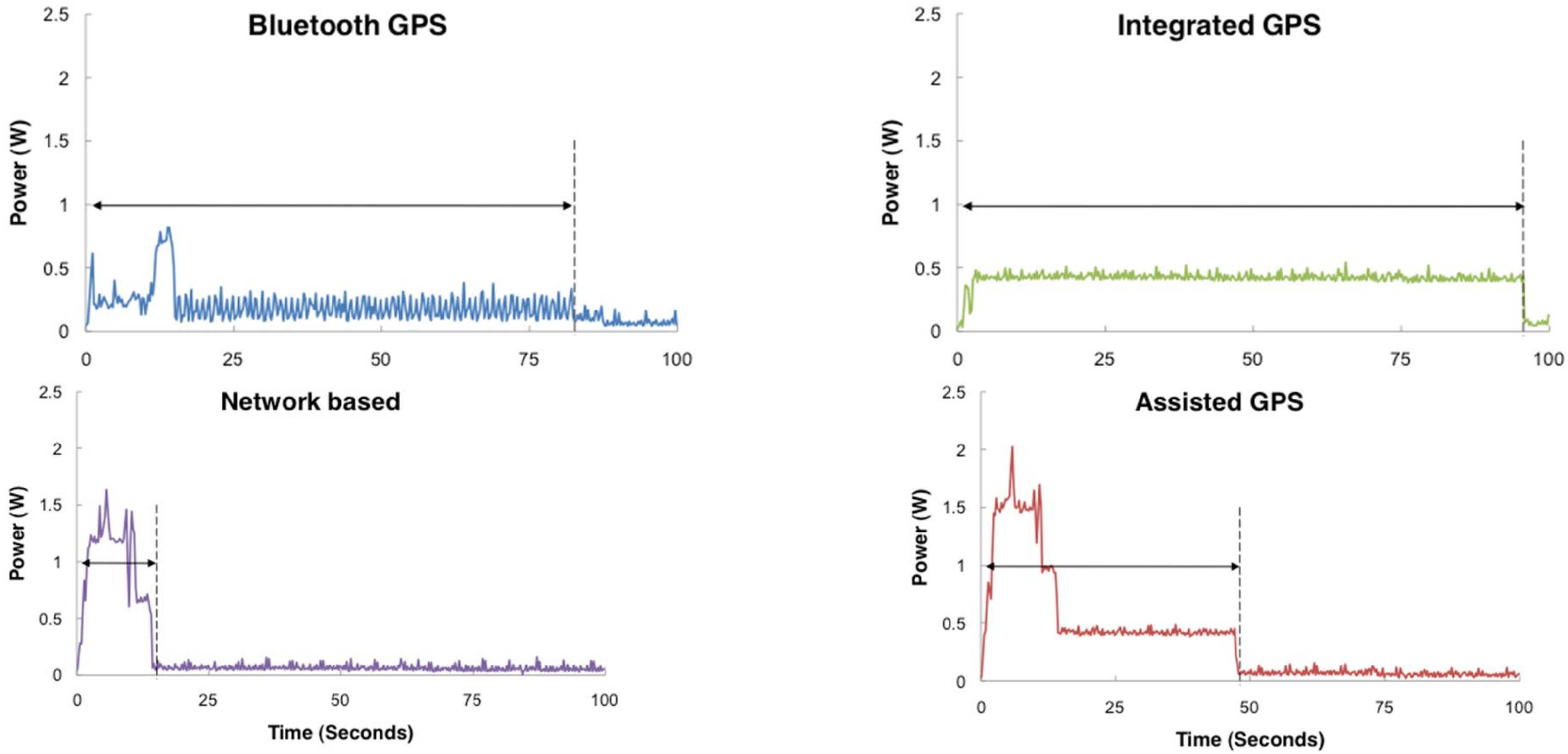
- **3 WBAN functions + 3 languages + 3 models**
  - ***QDA: QRS Detection, AES: Encryption, ZIP: 10 min data (180KB)***
- **PyS60 Energy >> J2ME > C++**
  - ***Runtime environment overheads, memory management***
- **Programmer efficiency vs. WBANs battery**
  - ***Easy to program most often conflicts with energy efficiency***
  - ***Resource constrained environment & unlikely to improve***
  - ***Tradeoffs tilt toward energy efficiency***

Energy Challenge – Sensing



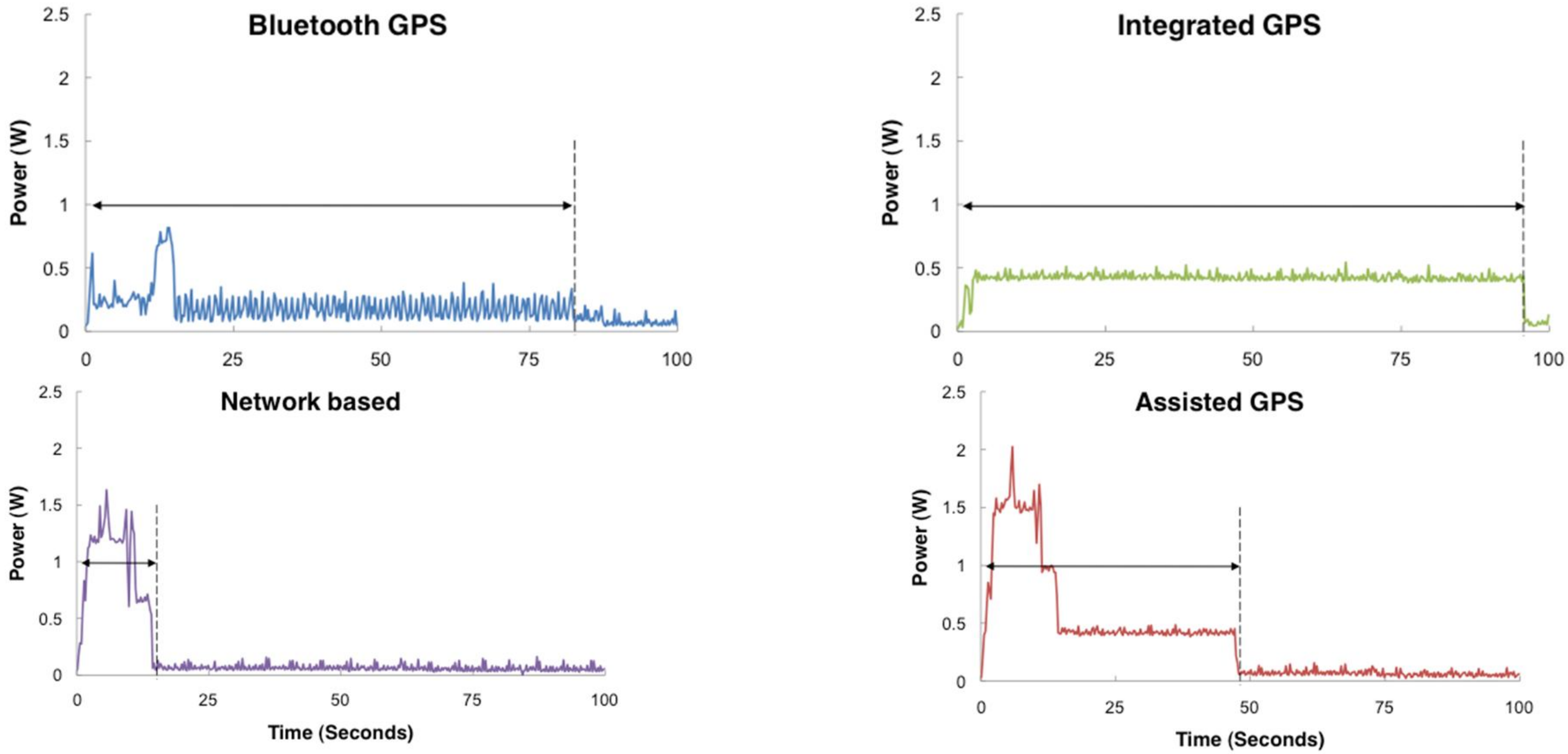
- **Dramatic battery drain on N95**
  - ***200 hours standby time reduced to 5 hours***
- **Even without external sensors the in-built sensors drain battery**
  - ***GPS reading = 6.6 Joules***

One Example: GPS Sensing



- **Power consumption varies significantly with the type of GPS**
  - ***Nearly 2X more power for A-GPS over N-GPS***
  - ***A-GPS is accurate within meter***

One Example: GPS Sensing



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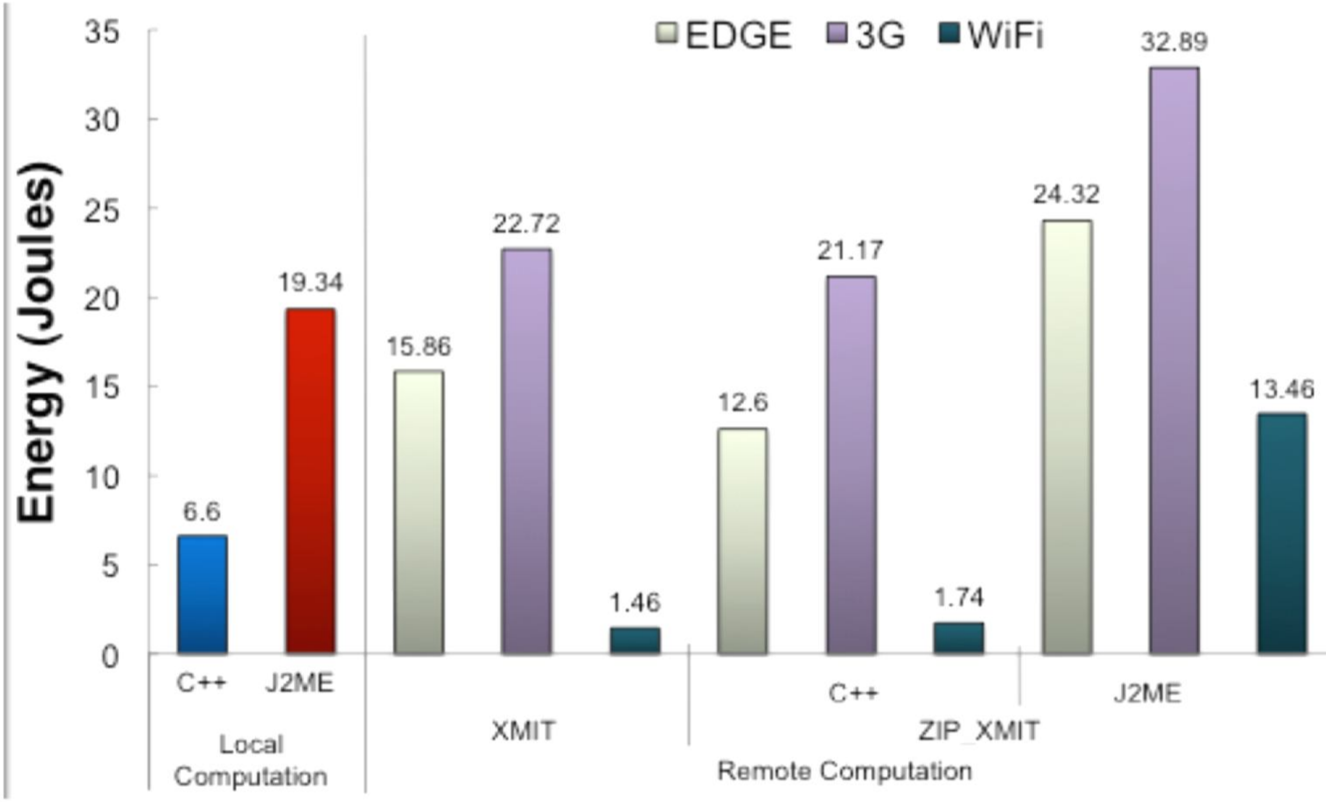
Compute vs. Communicate

- **WBAN data is analyzed for state detection, anomaly detection,…**
- **Two Choices:**
  - ***Analyze locally on mobile phone and send only interesting events to backend server***
    - ***What is interesting is user/scenario-defined***
  - ***Do nothing on phone and send everything to backend***
    - ***Backend transmits anomaly data to mobile phone***
- **Trading local compute cost with communication cost**
  - ***Selection must be dynamic for optimal energy consumption***

Local Vs Remote Compute: QDA



- **J2ME: Local 19J, WiFi XMIT: 1J, ZIP EDGE:24J, EDGE: 16J**
- **WiFi is preferable BUT uncommon scenario in free-living WBAN**
- **Else remote compute on EDGE (& no ZIP) better for small pkts**
- **Even a simple example has no clear choice**
  - **Signal quality issues make choices even more uncertain**
  - **Computational demands differ per WBAN & even vary dynamically**

Active Energy API

- **Provide a set of API for designers to obtain system services at the lowest energy cost, such as GPS, data transmission**
- **API automatically selects the best implementation**
  - ***Implementation relies on Active Energy Profiling framework***
- **Current APIs:**
  - ***Initialize()***
  - ***StartMonitoring()***
  - ***StopMonitoring()***
  - ***GetPosition()***
  - ***MakeDecision()***
  - ***SendData()***

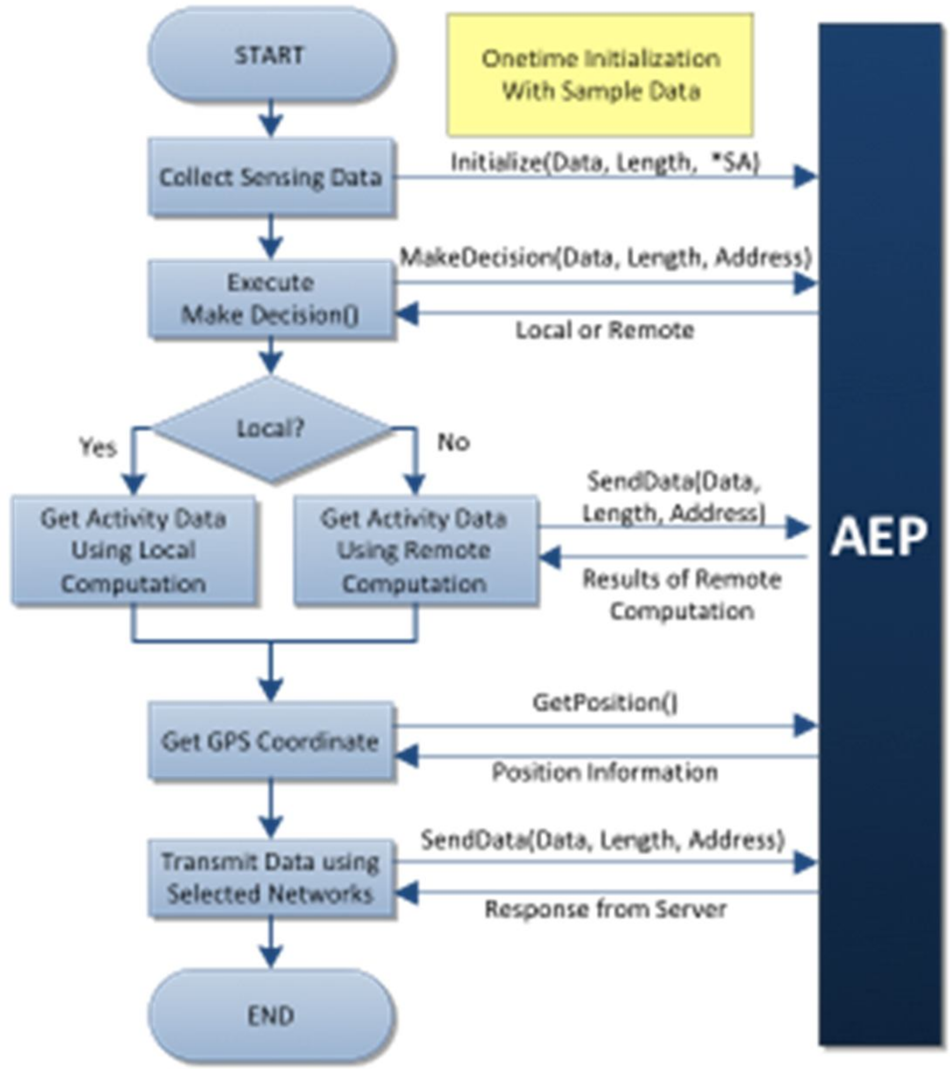
Active Energy API

- **Initialize (Sample Sensor Data, *Anal Func)**
  - ***Called on system start with sampled data and analysis function ptr***
  - ***Collects position-independent configuration parameters***
    - ***Compression cost, ratio***
    - ***Local computation cost on sampled data***
    - ***Store in Config DB***
- **MakeDecision (Sample Data, Destination IP)**
  - ***Scan WiFi Aps***
  - ***Check config DB for position-dependent params***
  - ***If no match then use Active Energy Profiling***
    - ***Transmission costs for each network interface (scan WiFi Aps)***
    - ***Store profile data in DB (indexed by GPS)***
  - ***Compute local & remote costs***
- **GetPosition**
  - ***Calls GPS only if WiFi scan is 20% changed***

Combat Uncertainty with Active Energy Profiling

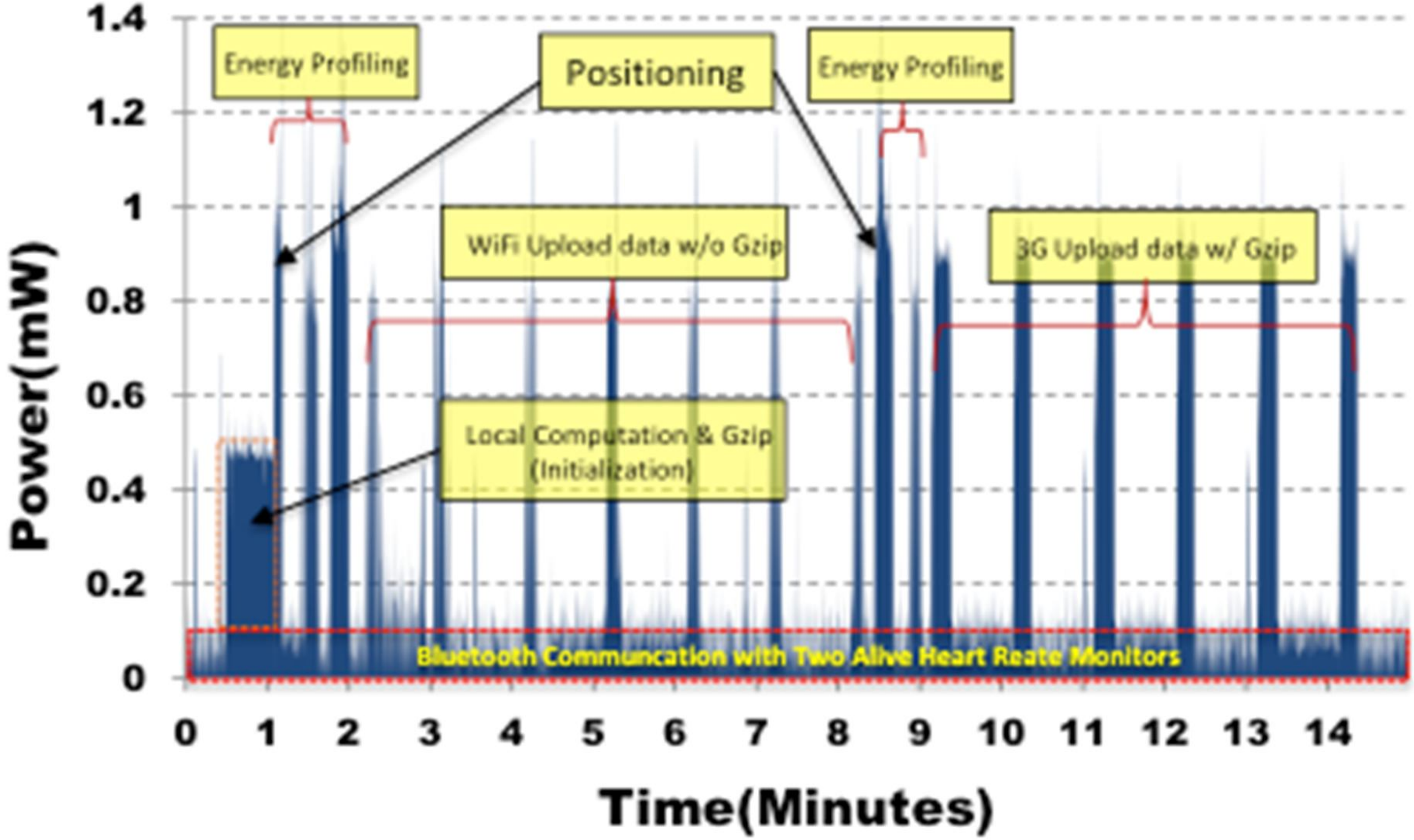
- **KNOWME Operation**
  - ***Sense continuously***
  - ***Find state every min***
  - ***Get position***
  - ***Xmit after 1 min***

Baseline Method



AEP Method

AEP in Action



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