Sensomax

Agent-based Decentralized Adaptive Data-gathering from Large-scale Wireless Sensor Networks

JavaOne Conference 2014

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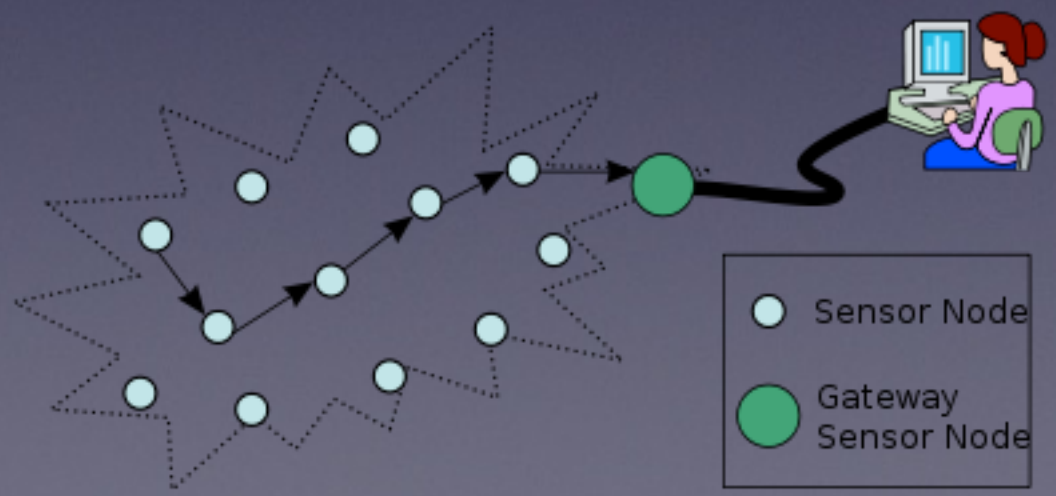
sphere

The UK Research & Training Initiative
LSCITS
Large Scale Complex IT Systems

STANFORD UNIVERSITY

Wireless Sensor Network

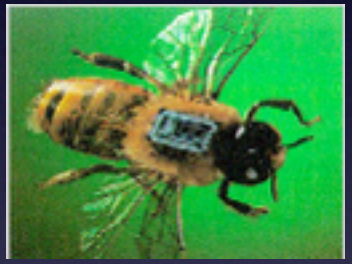
- *A **wireless sensor network (WSN)** consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, light, sound, pressure, etc. and to cooperatively pass their data through the network to a main location.*



Advantages of WSNs

Advantages of WSNs

- *Cheap*
- *Small-sized*
- *Wireless Communication*
- *Easy installation*
- *Minimal infrastructure*
- *Covering large areas*



What are they good for?

Applications

Structural Health Monitoring

Bridges

- ***According to a 2009 estimate by the U.S. Society of Civil Engineers, more than one in four U.S. bridges are either structurally deficient or functionally obsolete.***

(Minneapolis, 2007) 13 people dead and 145 injured

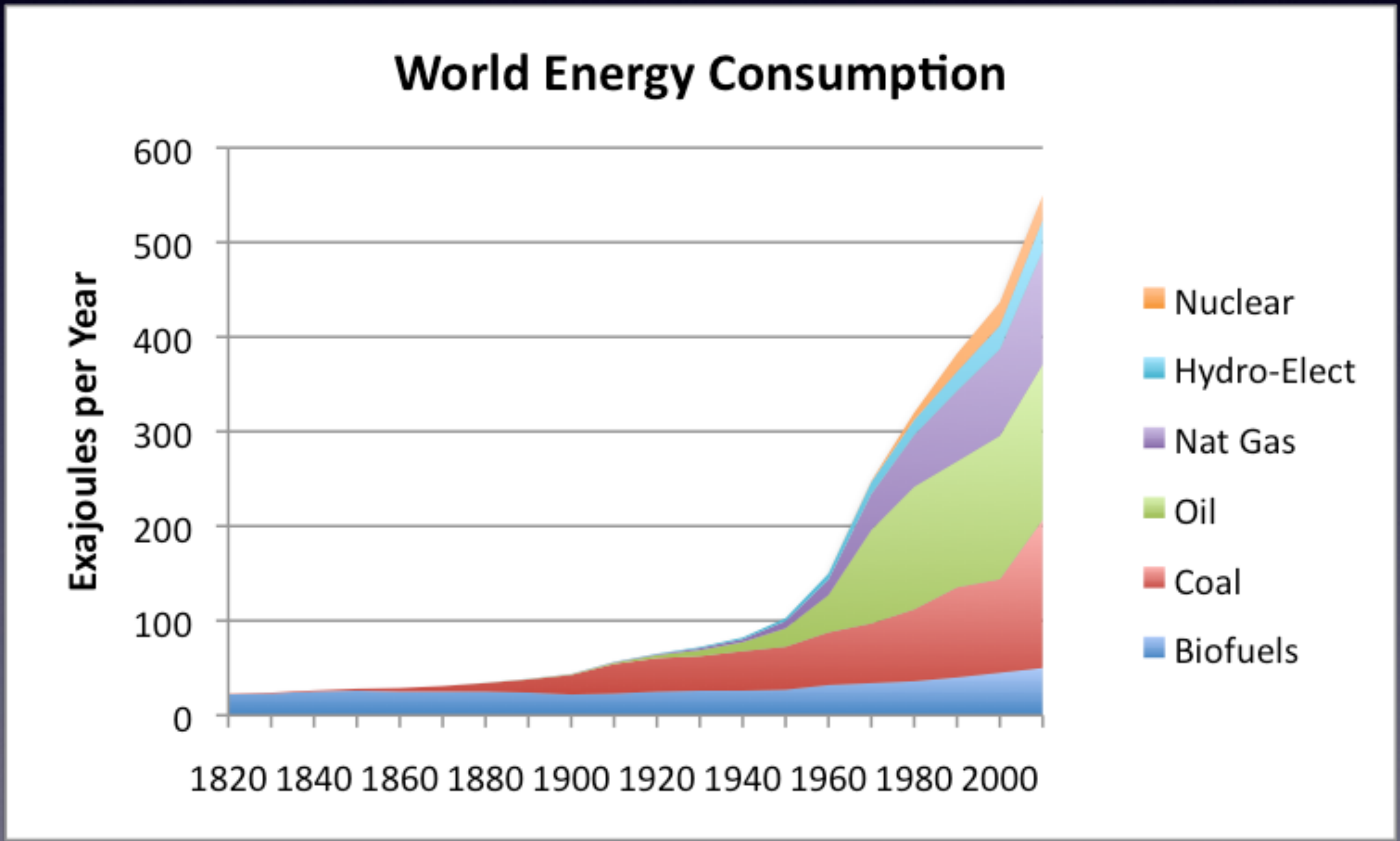
Power Stations

- ***More than 10% of the 422 nuclear power stations in the world are located in areas vulnerable to earthquakes and tsunamis.***

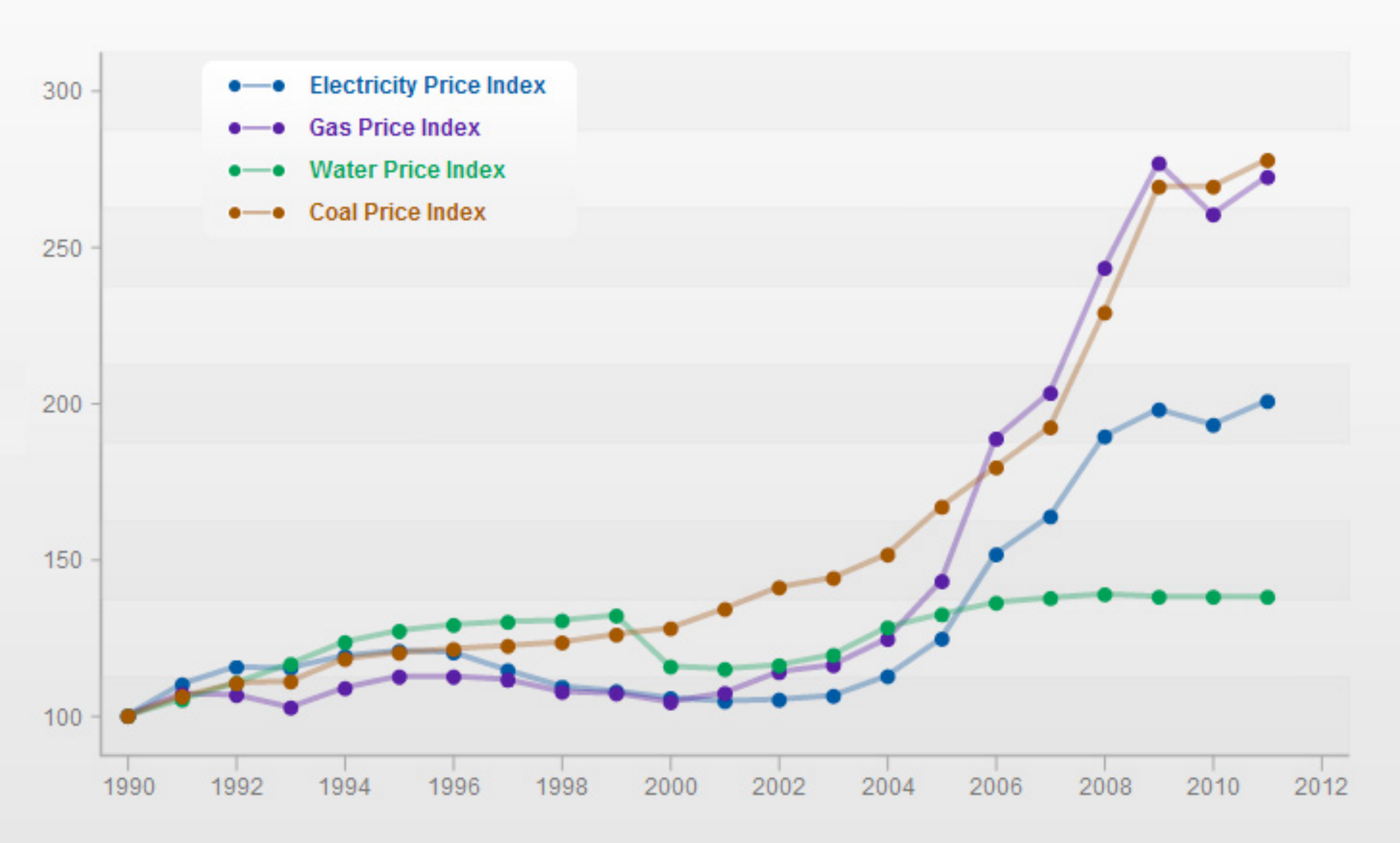
Fukushima I Nuclear Power Plant

Tōhoku earthquake and tsunami March 2011

Energy Management



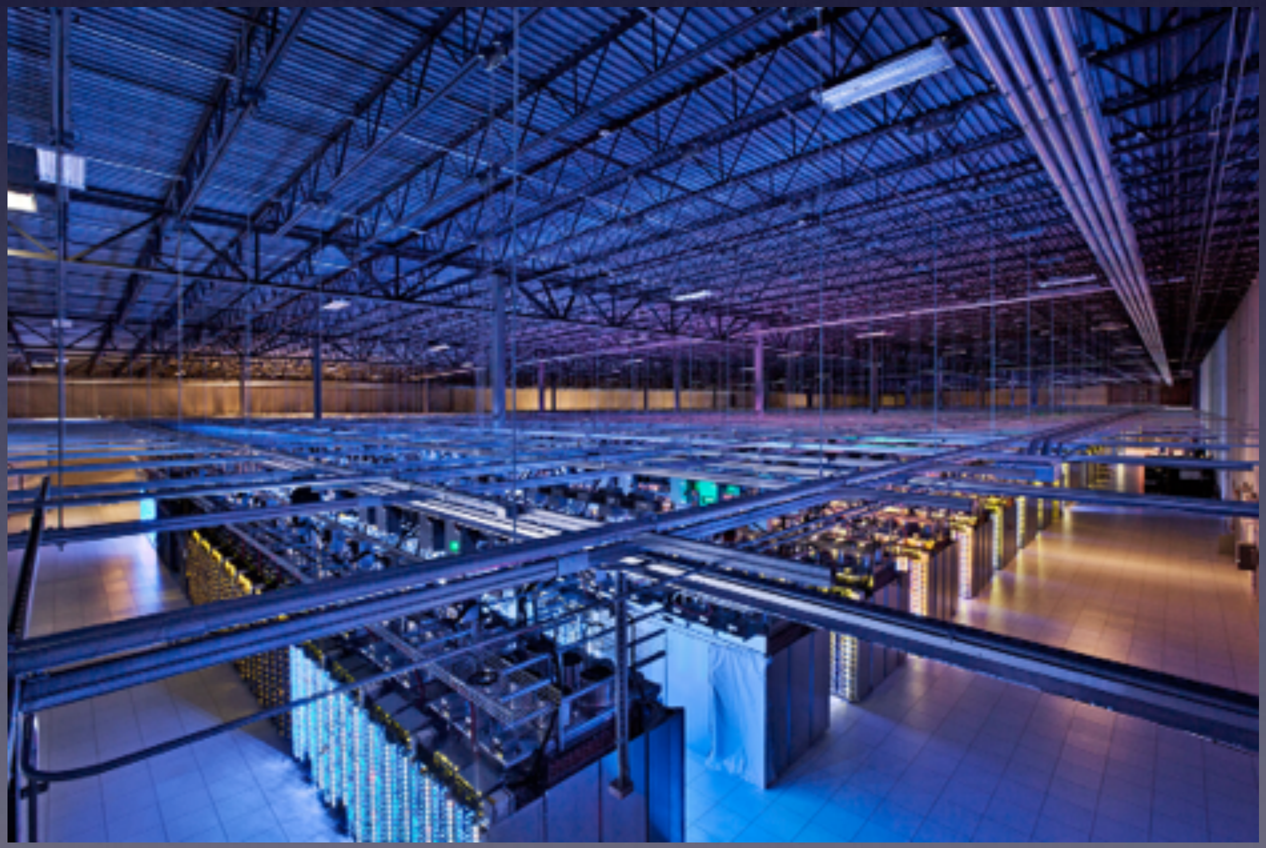
Costs of Utility Prices



Cost of utilities in the UK

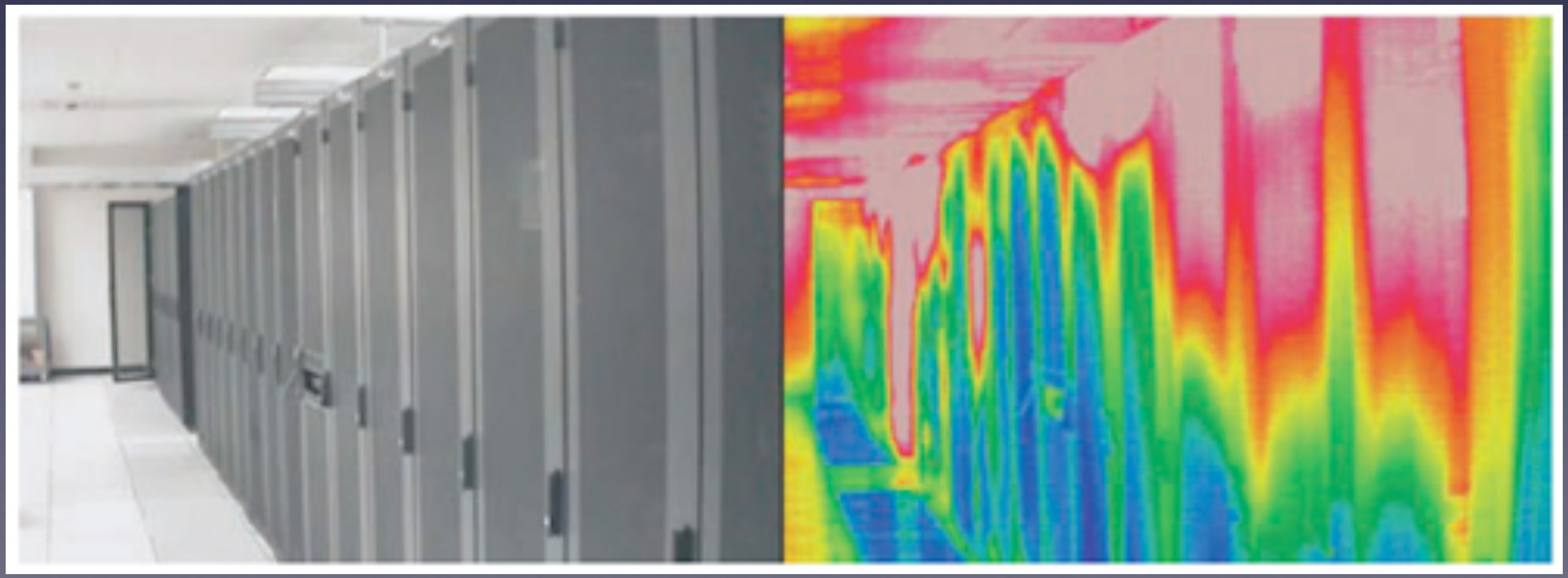
Data Centers

- ***Data centers use 38GW of power per year!***



Project Genome

- ***20-70% of total energy for cooling***
- ***Lack of visibility in operating conditions***

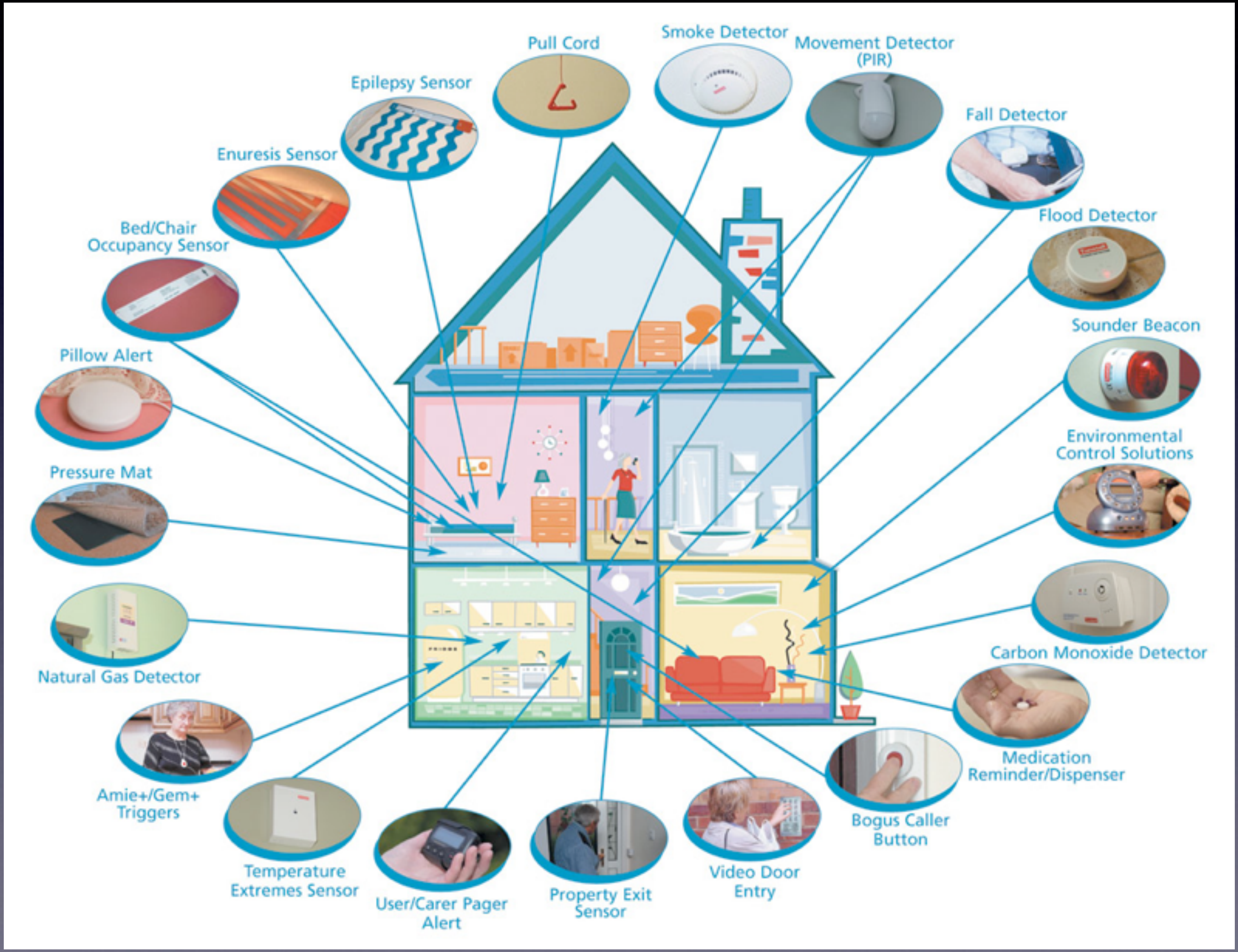


The infrared thermal Image of temperature across racks

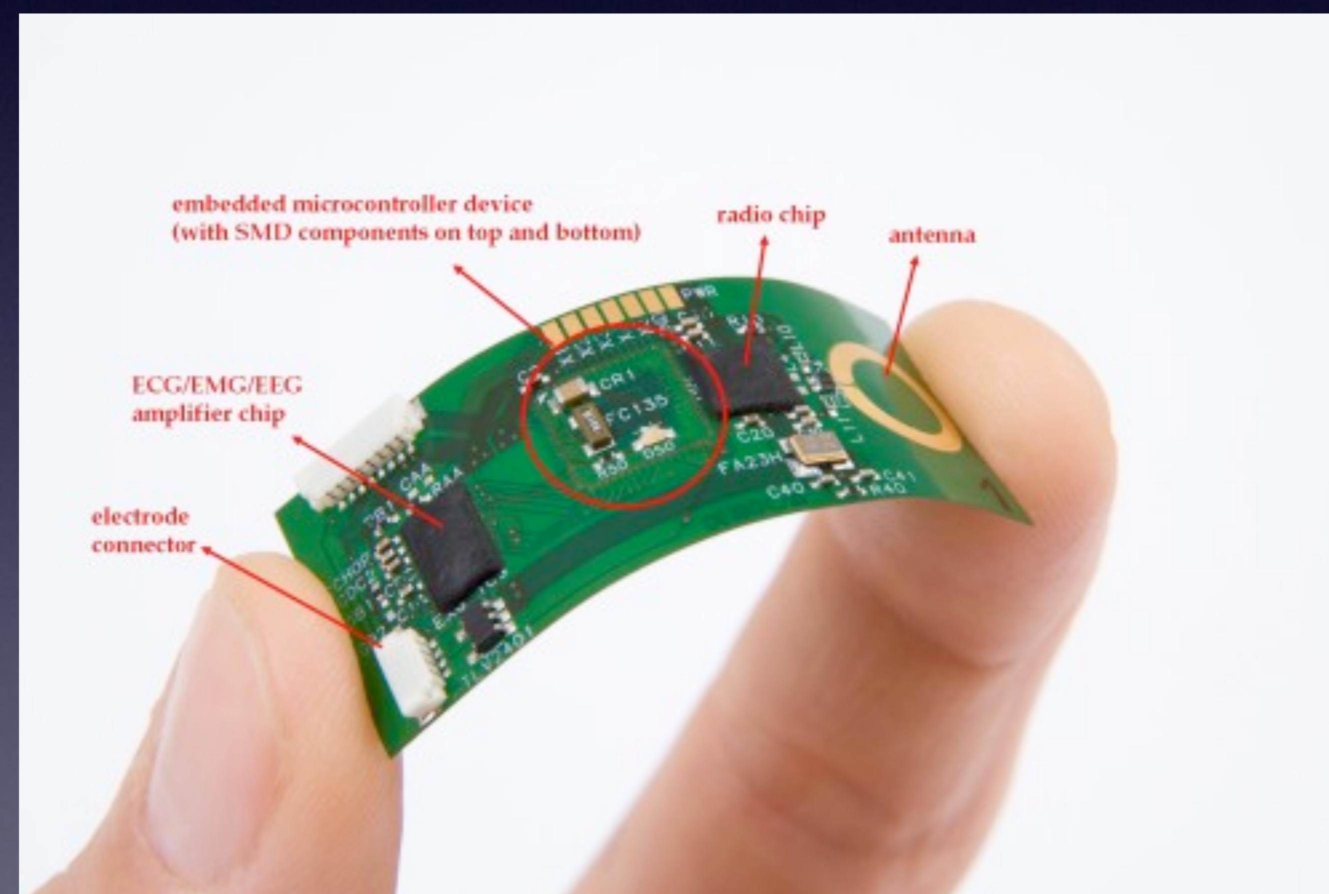
Agriculture

Greenhouses

Health and Safety



Health



Flexible wireless ECG sensor by imec

SPHERE

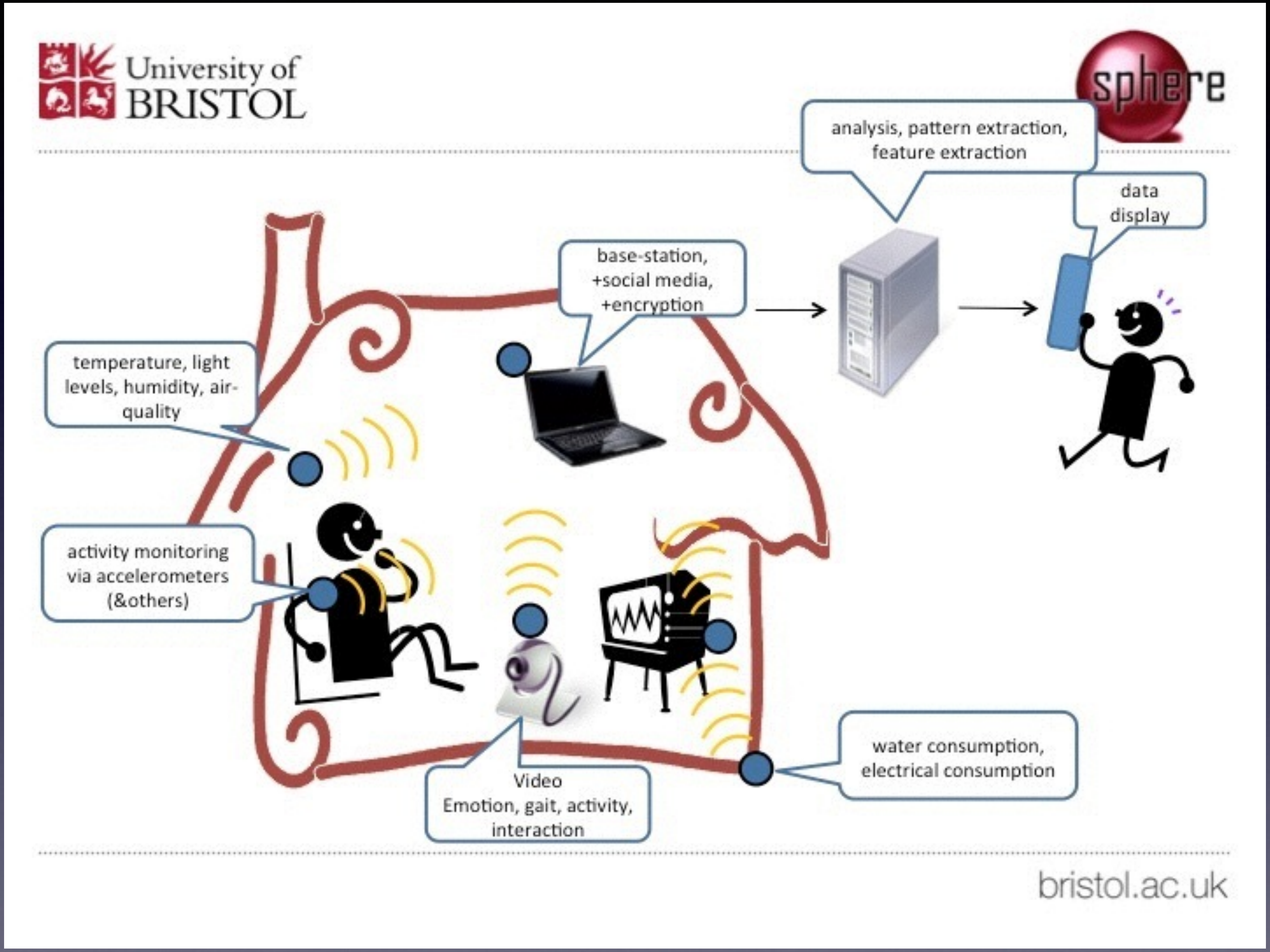
a Sensor Platform for HEalthcare in a Residential Environment

EPSRC Interdisciplinary Research Collaboration (IRC)

irc-sphere.ac.uk

bristol.ac.uk

“The vision of this proposal is not to develop fundamentally-new sensor technology specifically for individual disease conditions but rather to impact a range of healthcare needs simultaneously by employing data-fusion and pattern-recognition from a common platform of largely non-medical/ environmental networked sensors in a **home environment**”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sphere
analysis, pattern extraction, feature extraction
data display
base-station, +social media, +encryption
temperature, light levels, humidity, air-quality
activity monitoring via accelerometers (&others)
water consumption, electrical consumption
Video
Emotion, gait, activity, interaction
bristol.ac.uk

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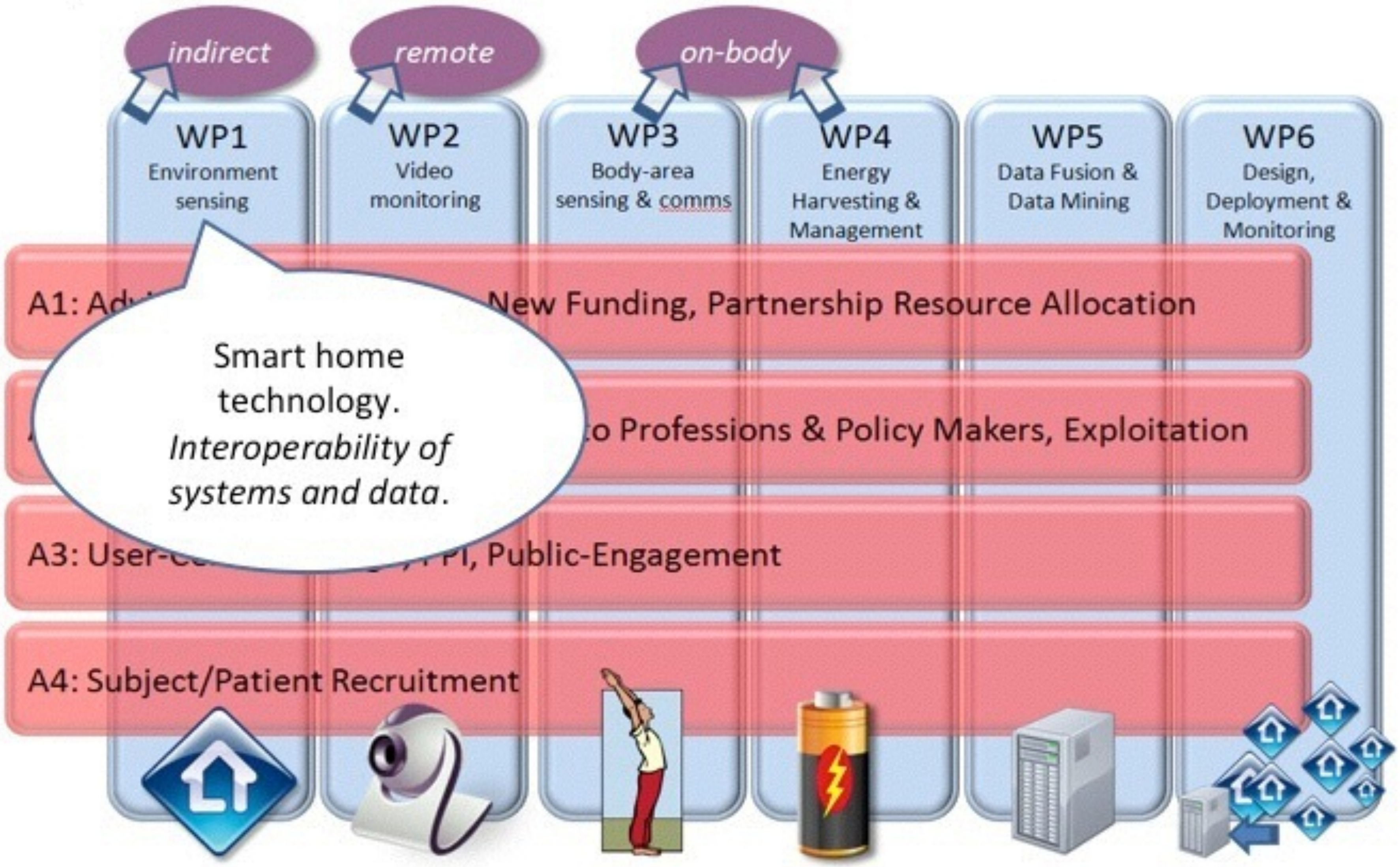
- The SPHERE bid was fully-funded in April 2013.
- Director Professor Ian Craddock, University of Bristol
- £12M over 5 years (plus £3M from industry and the Universities =£15M)

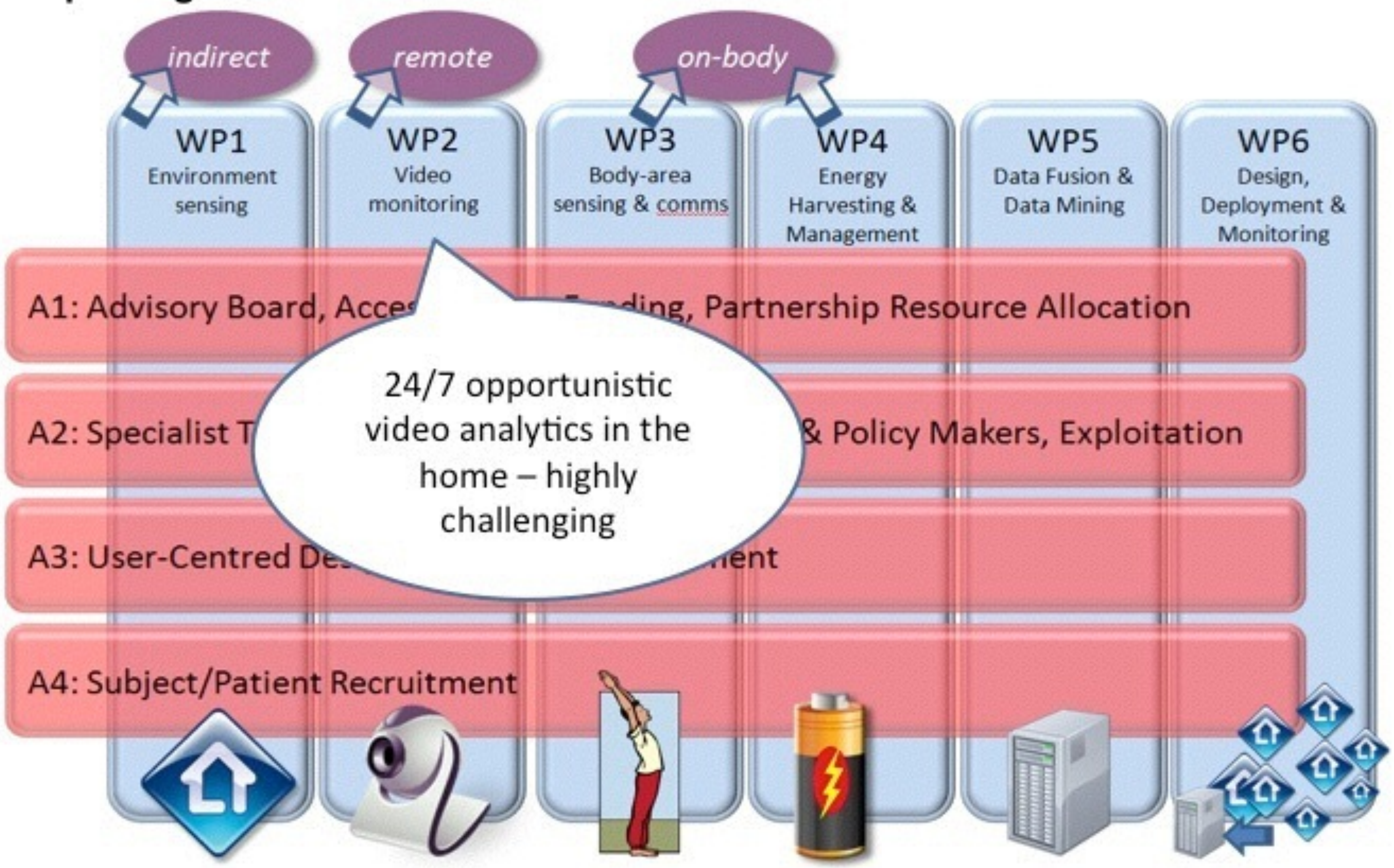
In collaboration with Southampton University (Health Sciences), Southampton University (Electrical Engineering), Reading University (Cybernetics), the Elizabeth Blackwell Health Research Institute, Bristol Vision Institute, Department of Experimental Psychology, School of Social and Community Medicine, School of Oral and Dental Sciences, the Centre for Medical Ethics, the Centre for Public Engagement, School of Clinical Sciences, Communications Systems & Networks Group, Intelligent Systems Group, Bristol Heart Institute, Interaction & Graphics Group, Bristol Health Partners, ALSPAC (Children of 90s), Bristol City Council, Knowle West Media Centre, Bristol NIHR Biomedical Research Unit in Nutrition, Diet & Lifestyle, Bristol NIHR Biomedical Research Unit for Cardiovascular Disease, IBM and Toshiba.

- Average number of people on project = 60.
- Project commenced in October 2013

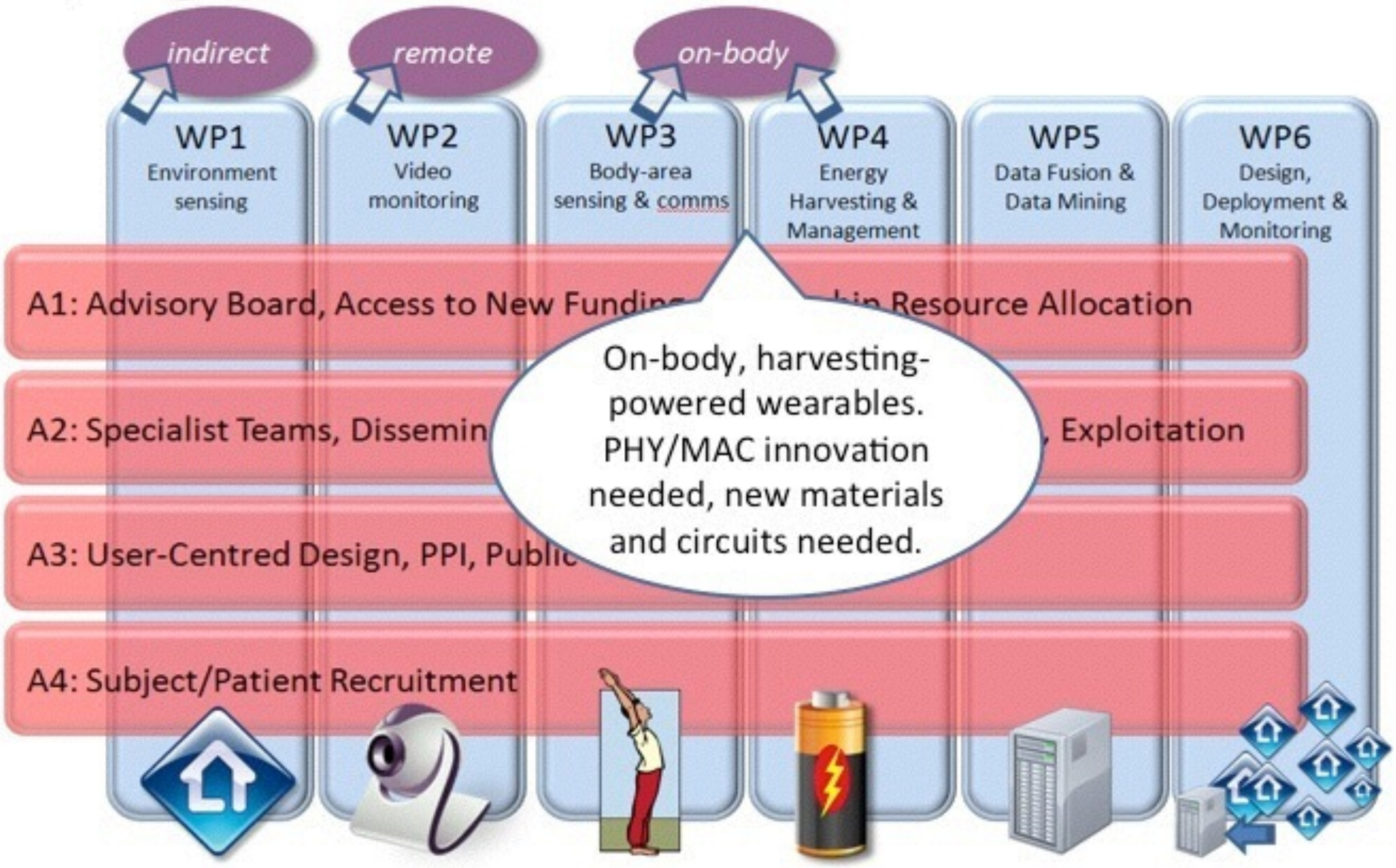
Workpackages

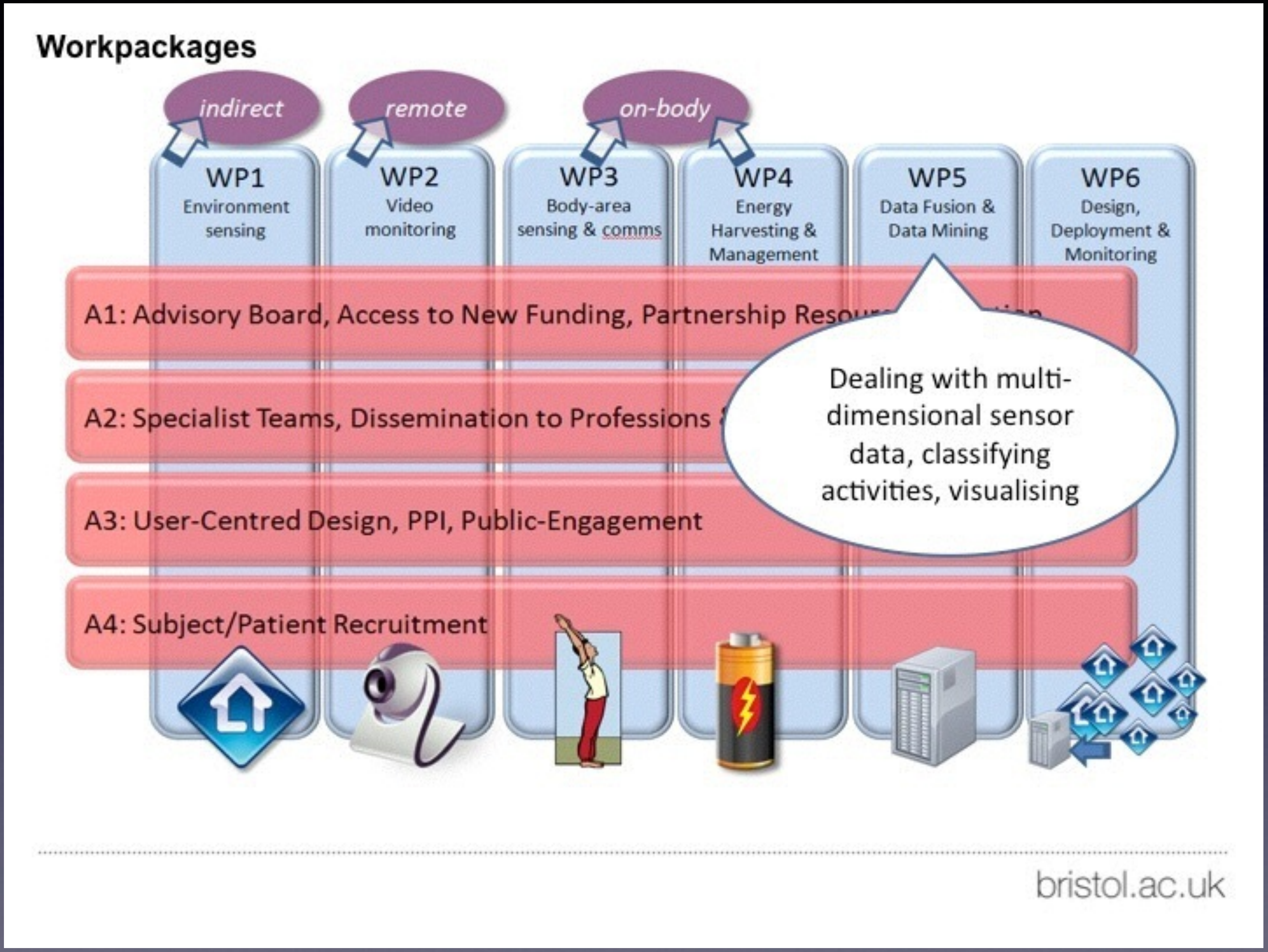


Workpackages

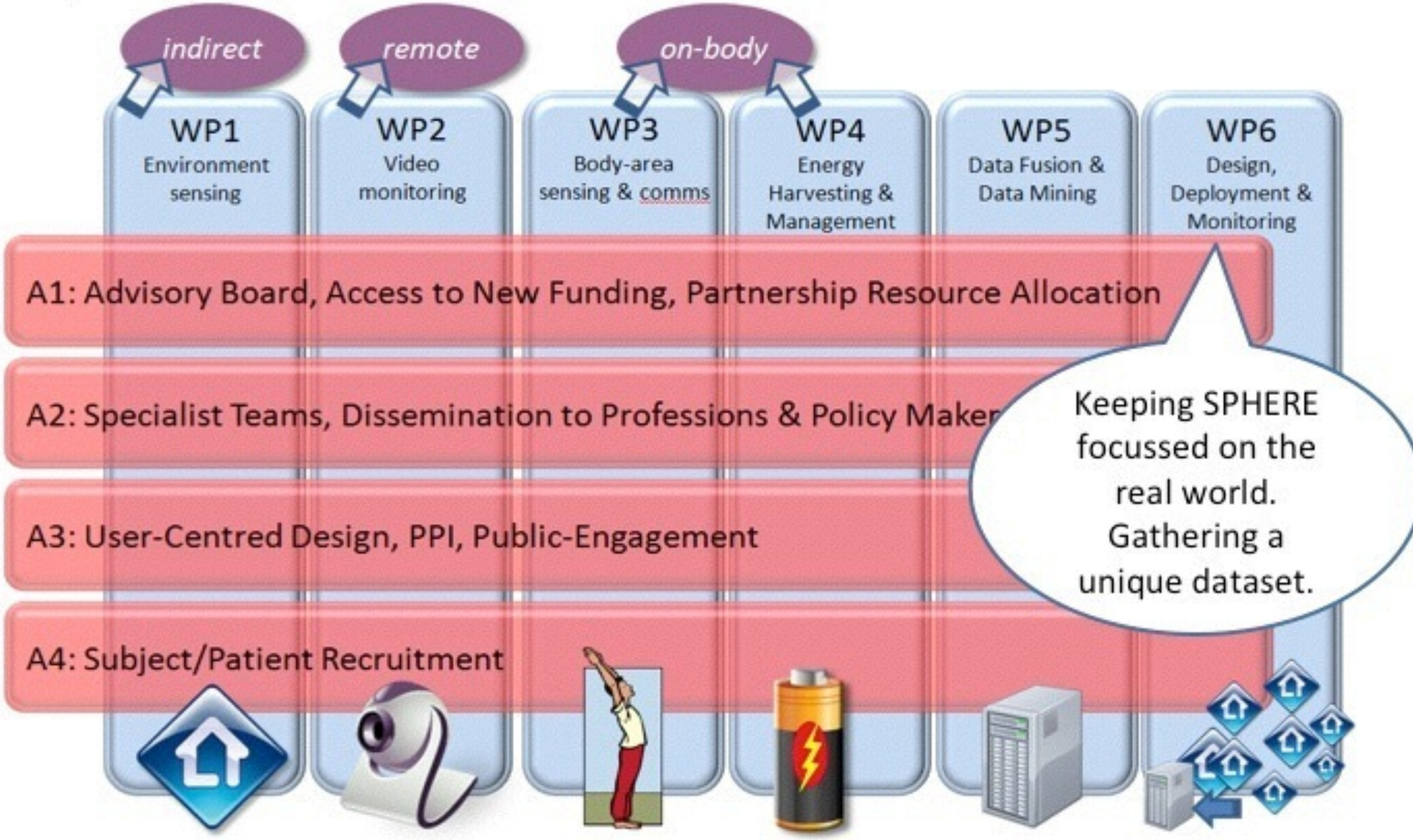


Workpackages

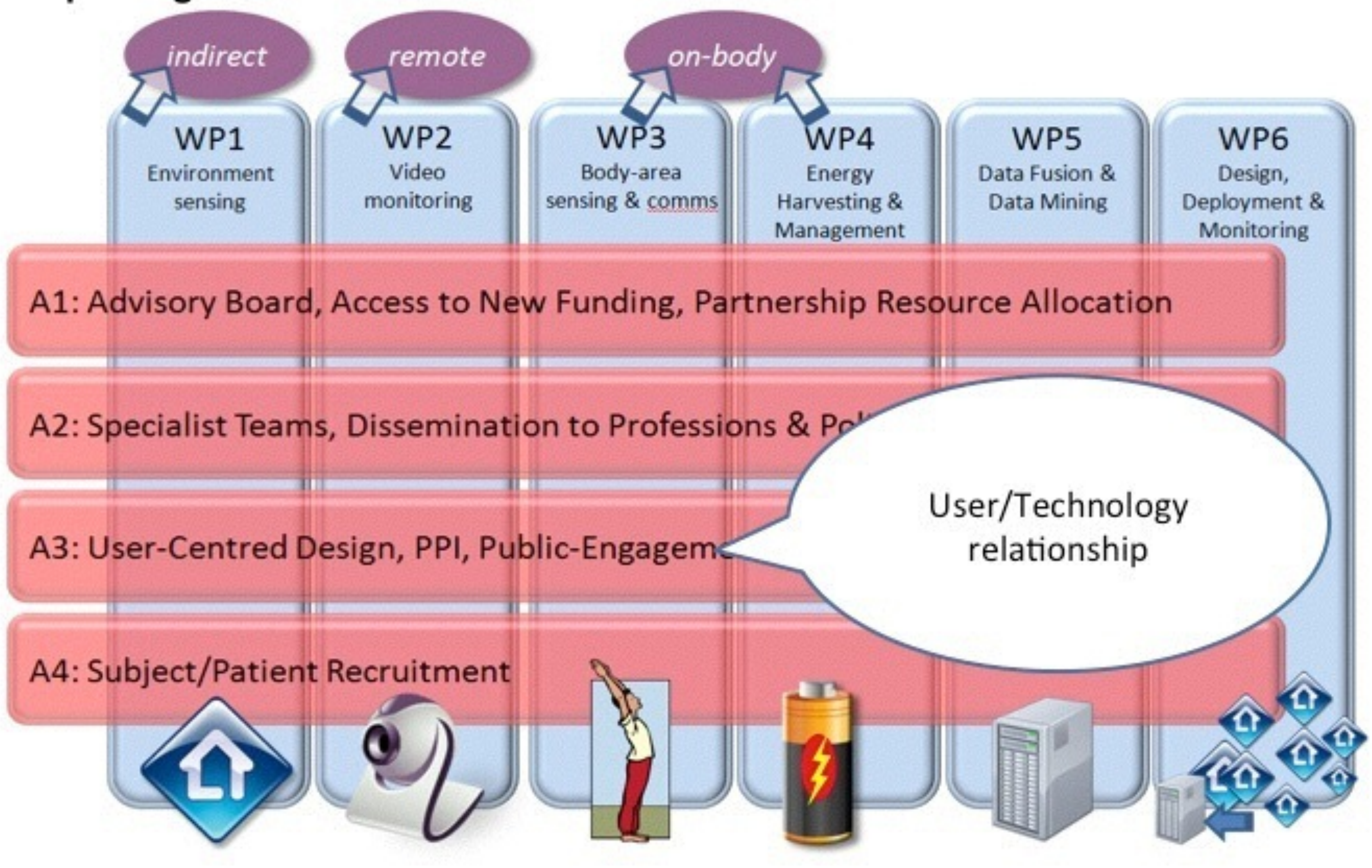



Workpackages
indirect
remote
on-body
WP1
Environment sensing
WP2
Video monitoring
WP3
Body-area sensing & comms
WP4
Energy Harvesting & Management
WP5
Data Fusion & Data Mining
WP6
Design, Deployment & Monitoring
A1: Advisory Board, Access to New Funding, Partnership Resou
A2: Specialist Teams, Dissemination to Professions
A3: User-Centred Design, PPI, Public-Engagement
A4: Subject/Patient Recruitment
Dealing with multi-dimensional sensor data, classifying activities, visualising
bristol.ac.uk

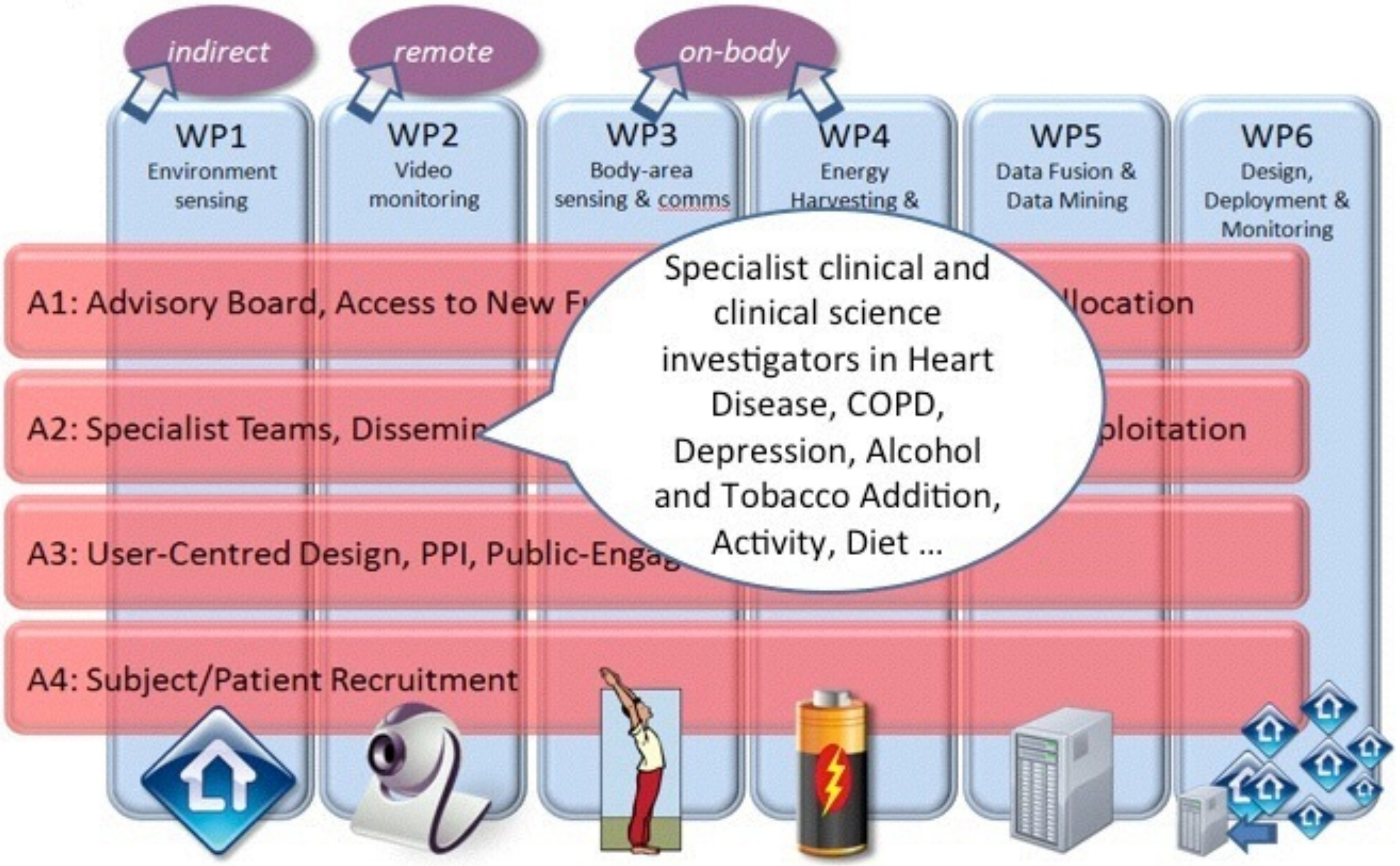
Workpackages



Workpackages



Workpackages



Next steps

- Answering emerging clinical questions from the Medical Faculties (e.g. Social and Community Medicine) and industry/NHS via a pre-proposal proof-of-concept requires data.
- This has all been done in lab environments already – the interesting questions are what we observe at home.

SPHERE has acquired a small house in central Bristol in August.

The house is being fitted with the version 1.0 of our sensor infrastructure.

There will be people living in the house from Jan 2015.

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Conclusions:

- SPHERE will advance the state of the art in:
  - ultra low power communications
  - on-body energy harvesting
  - video analytics in unconstrained environments
  - extraction of meaning from complex uncertain data sets.
  - the understanding of user/technology interaction in the home for healthcare.
- SPHERE's team will connect:
  - clinical need to engineers and computer scientists
  - emerging clinical research to evolving new technology.

Constraints of WSNs

- ***Limited Energy Capacity***
- ***Low Processing***
- ***Low Memory***
- ***Highly Coupled HW & SW***

Existing Solutions

- *Highly-Coupled Operating Systems*
- *Application-specific programs*
- *No multi-tasking support*
- *Centralized topology/behavior*
- *Unscalable*
- *Updating/re-Programming the nodes*

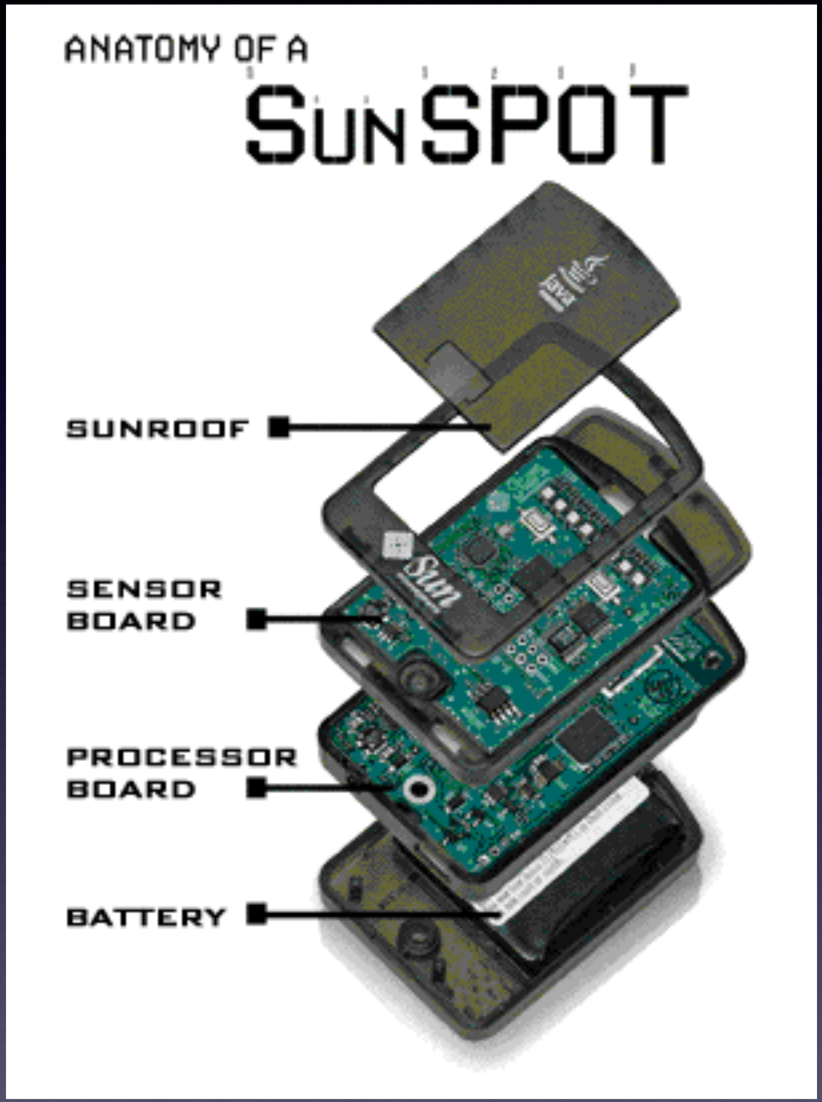
Solution??

Sensomax

Features:

- *Agent-Based Model*
- *Adaptable to application requirements*
- *Applying Dynamic changes at Runtime*
- *Muti-Tasking support*
- *Serving multiple applications concurrently*
- *Decentralized/Centralized task execution*
- *In-network & inter-cluster aggregation/Processing*

Sun Spot



ANATOMY OF A
SUNSPOT
SUNROOF
SENSOR BOARD
PROCESSOR BOARD
BATTERY

Sun Spot

Sensors

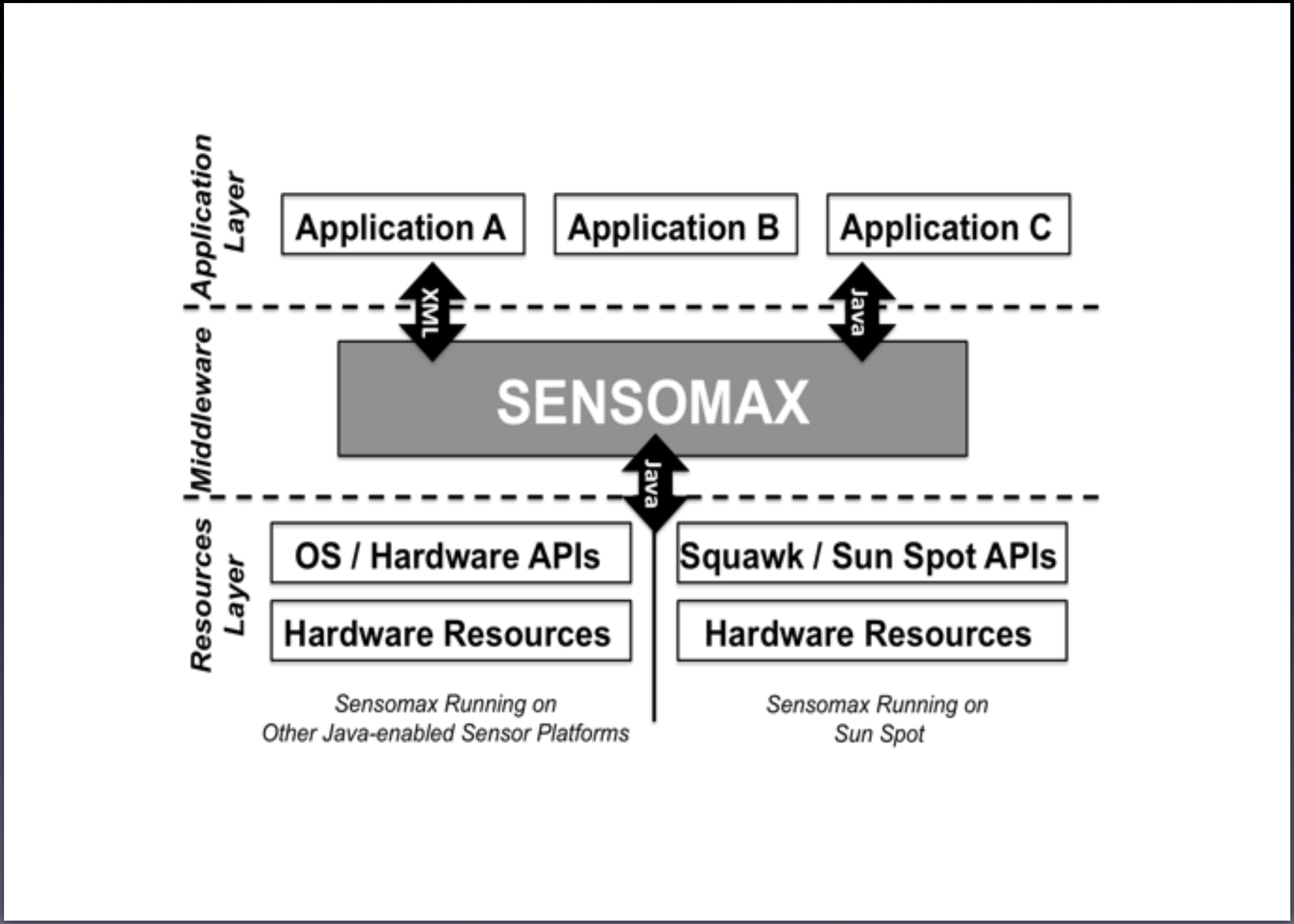
I/O

Sensomax

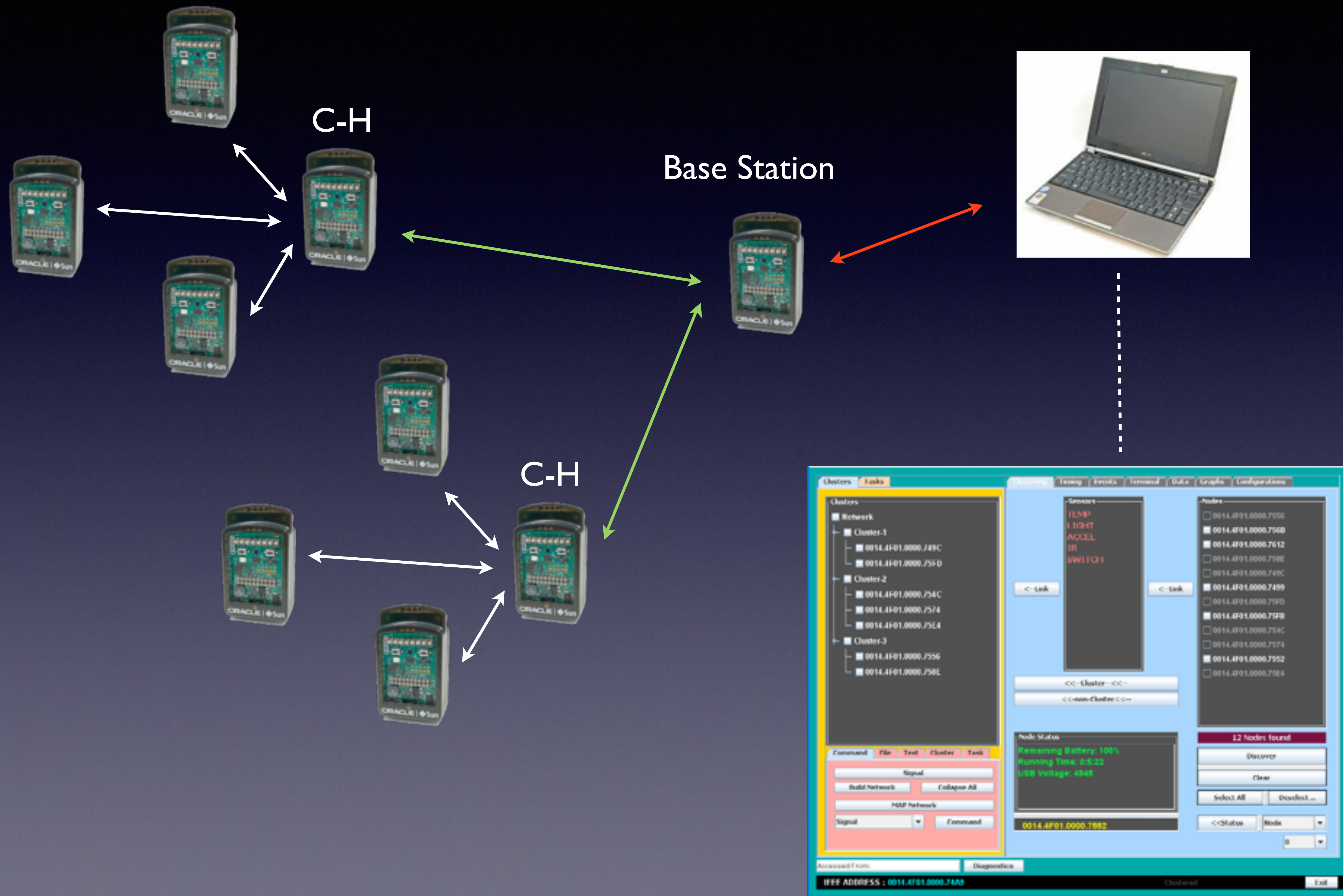
JVM

ARM

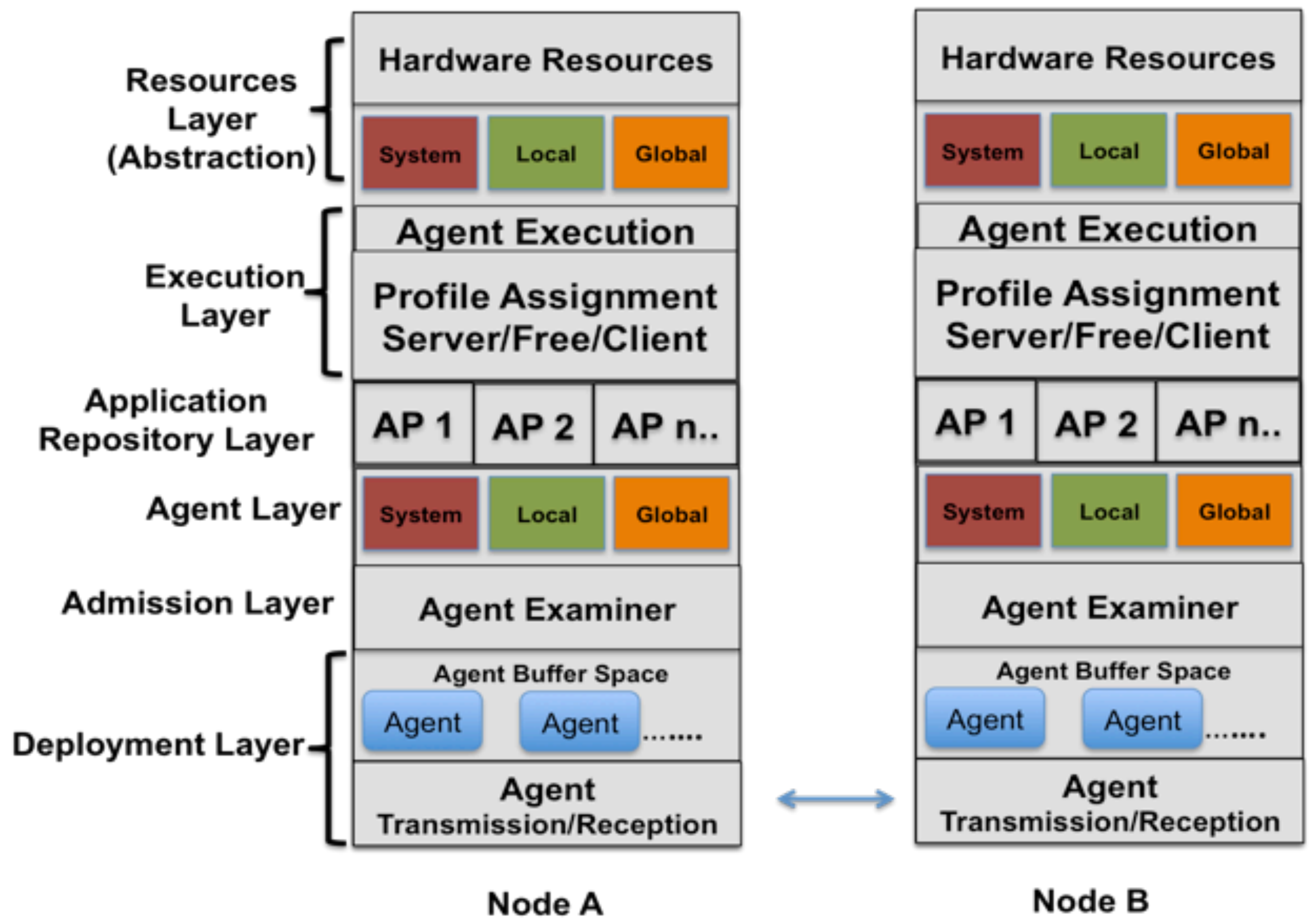
Architecture



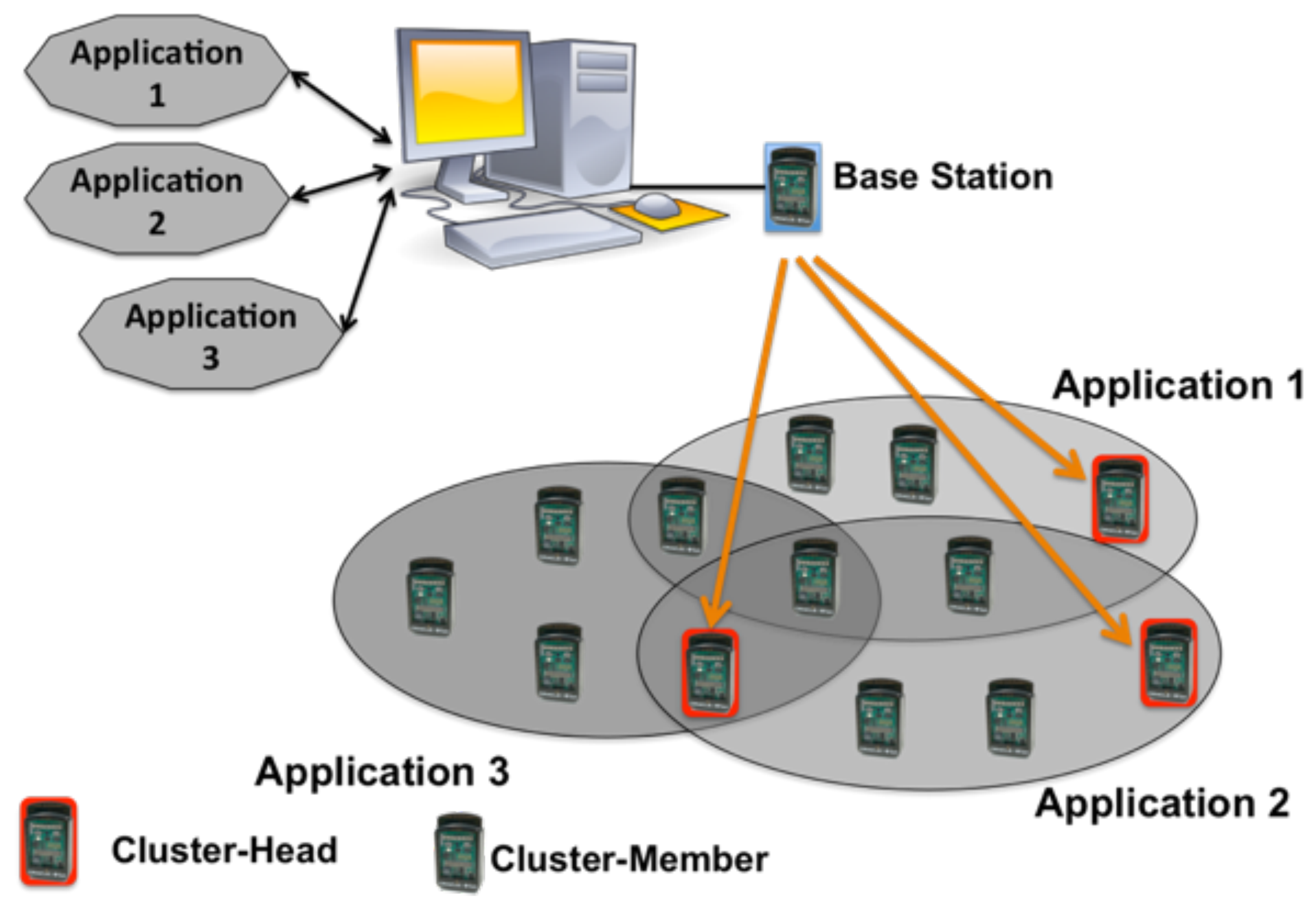
User Interface



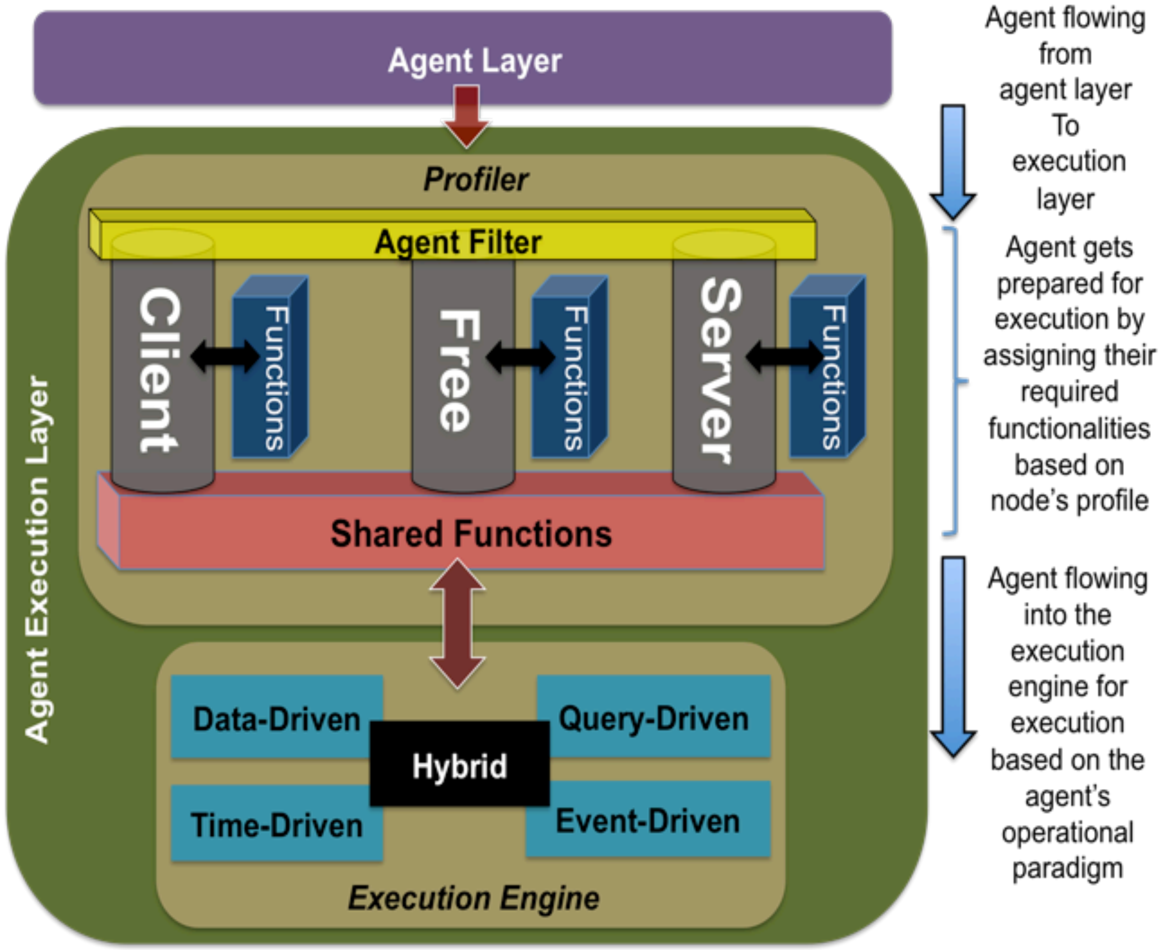
Architecture: Agents

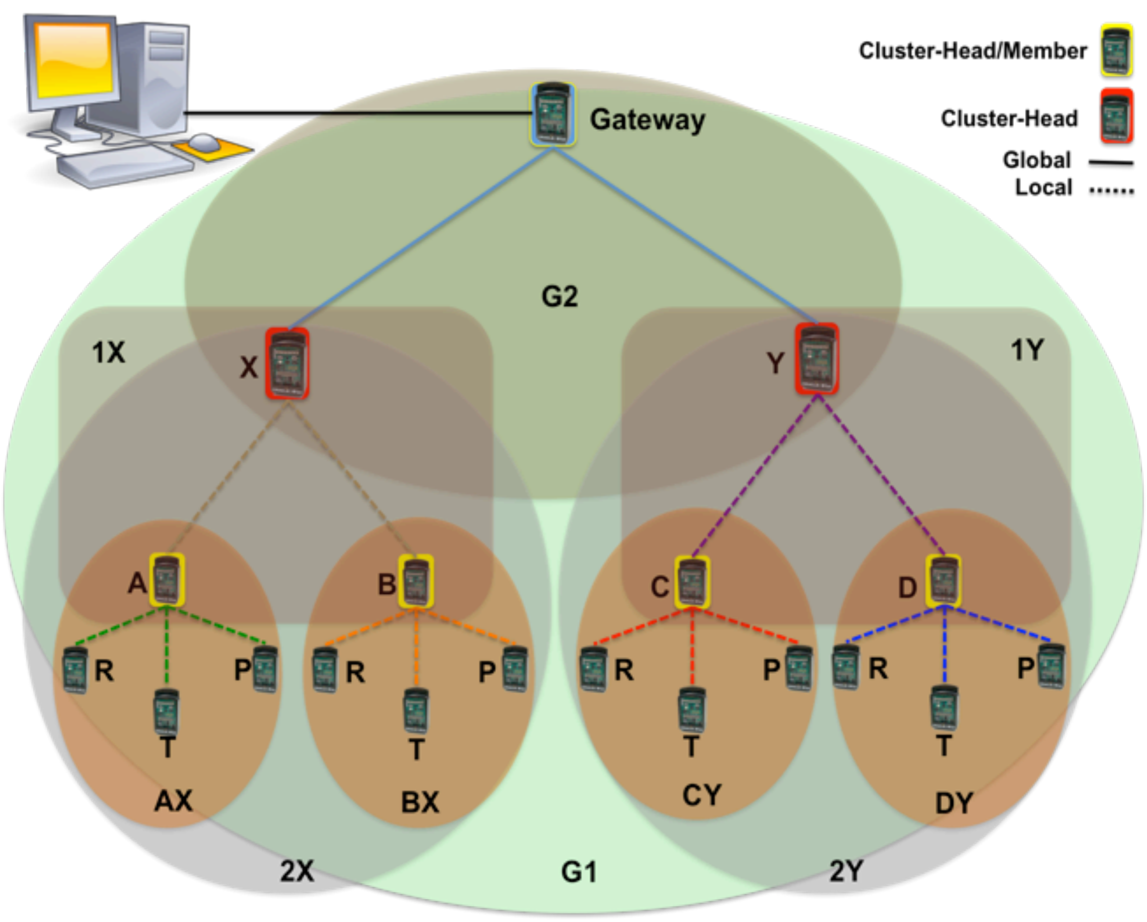


Concurrency

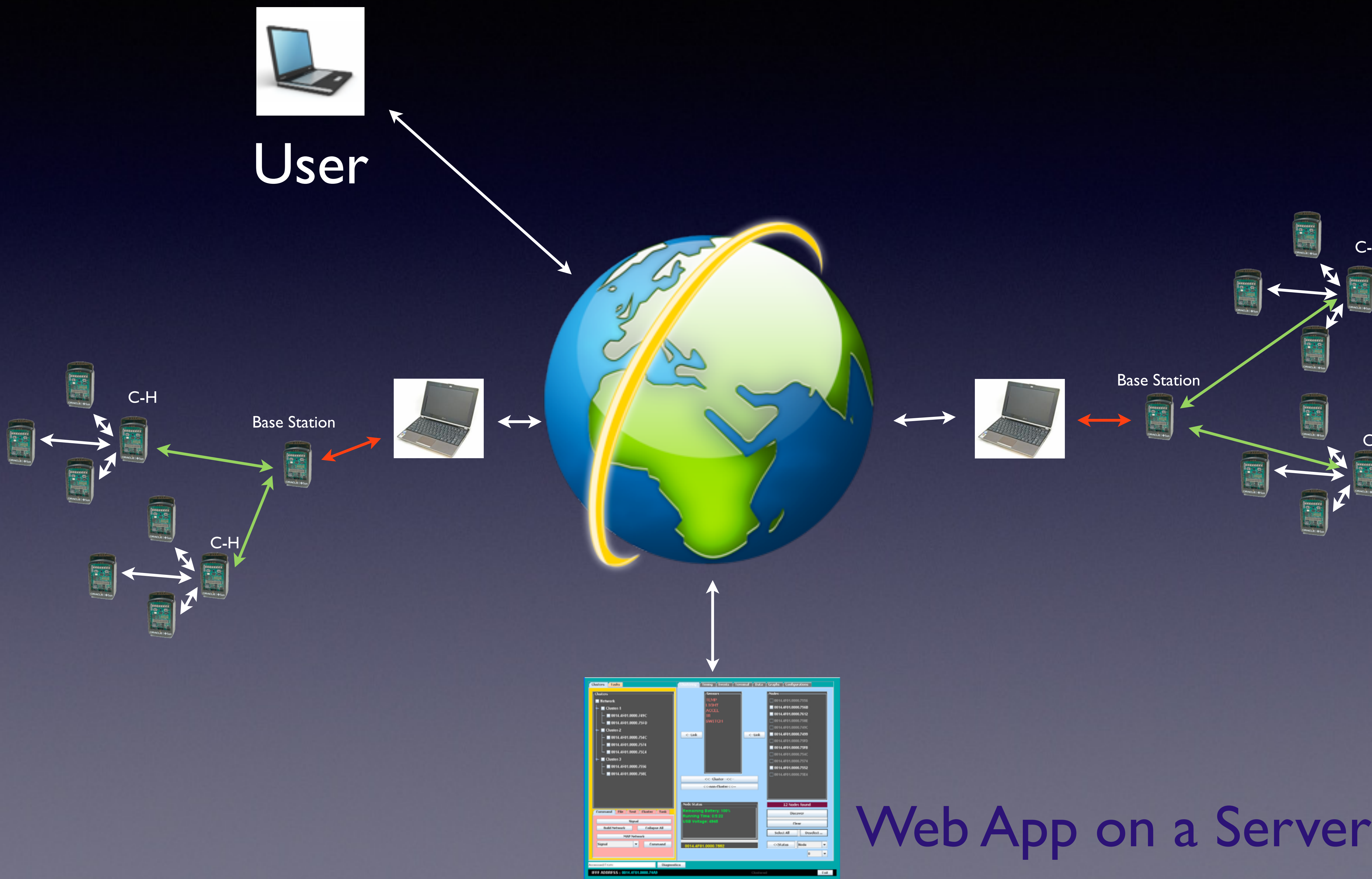


Operational Paradigms

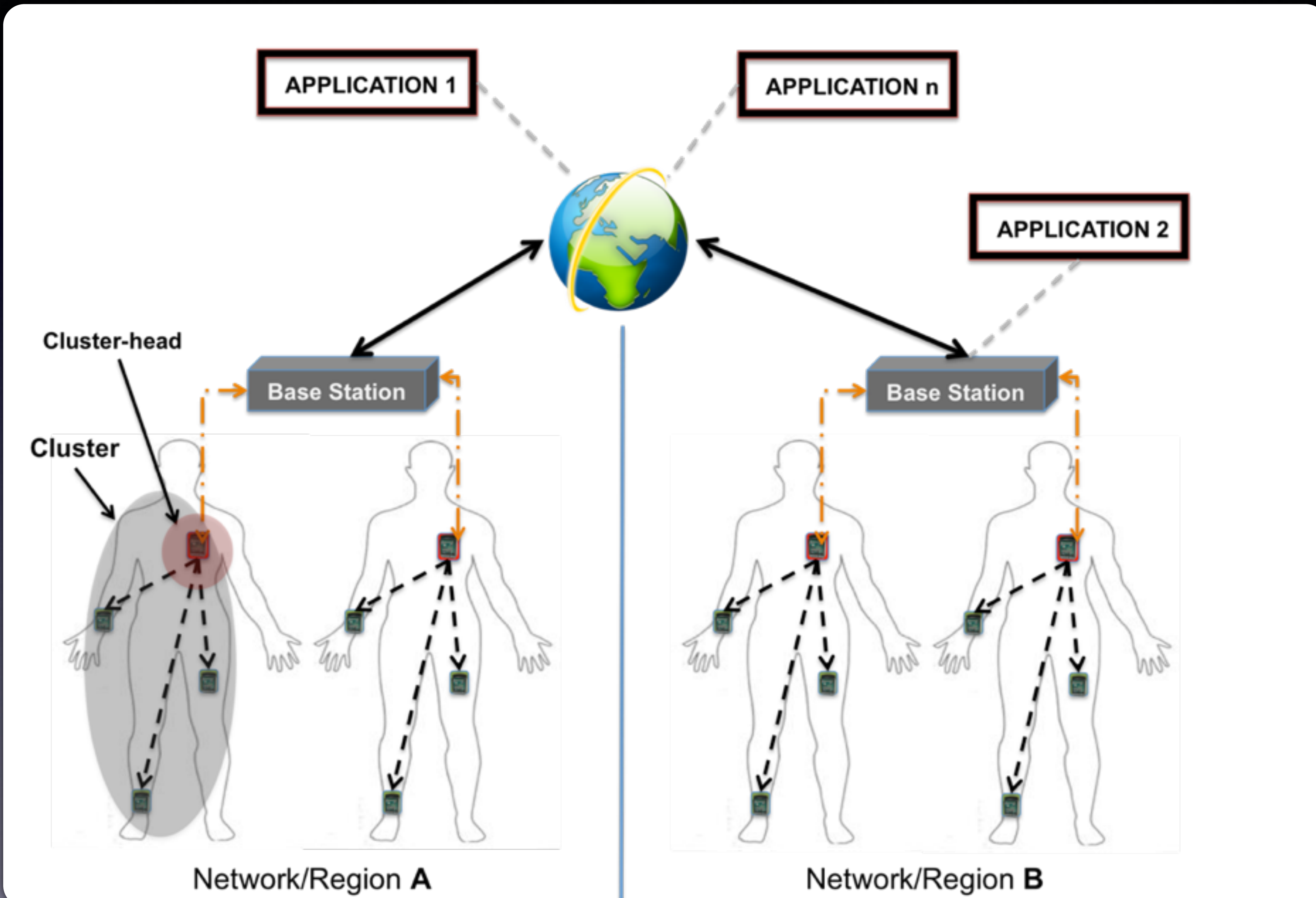




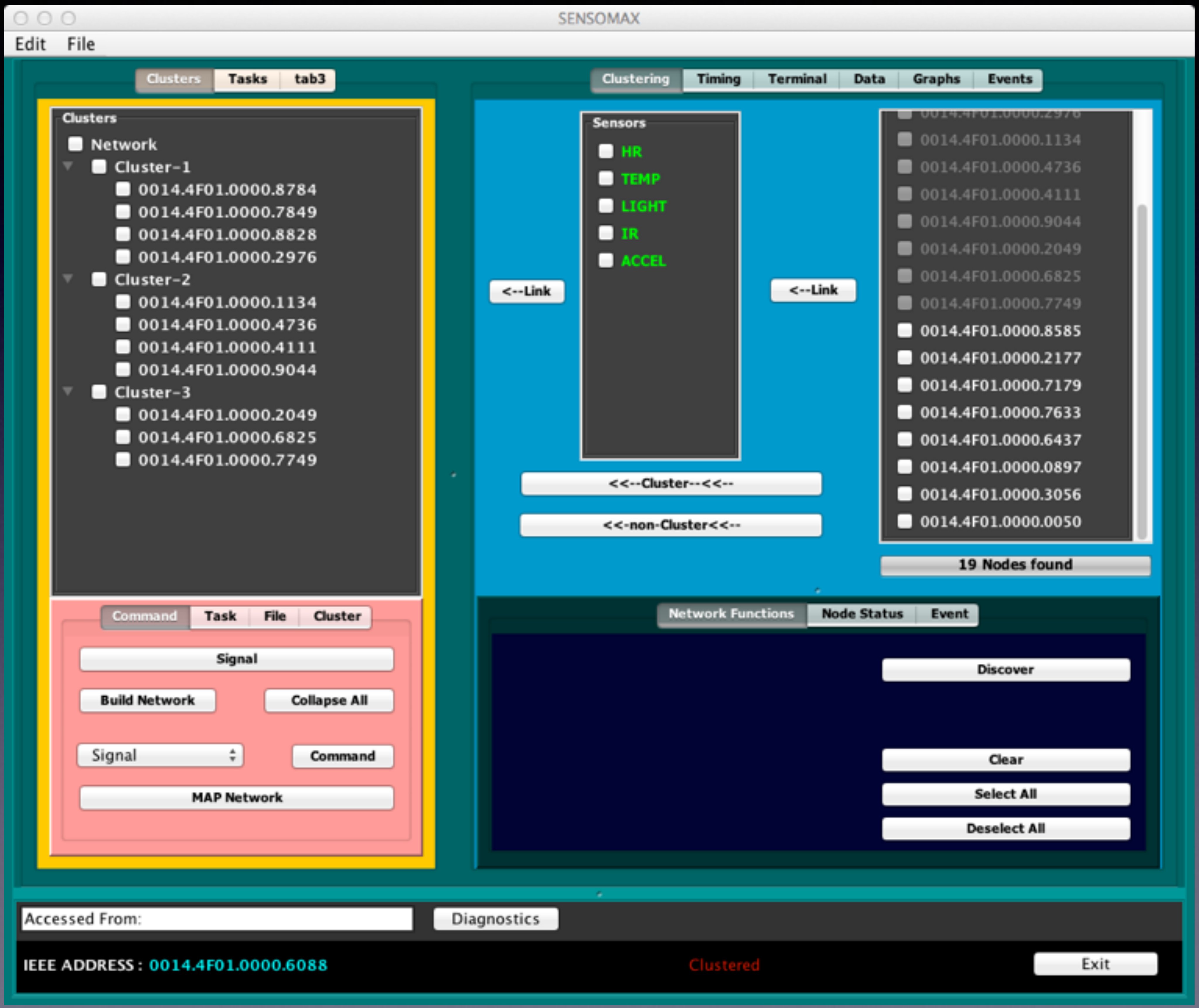
High-Level Architecture



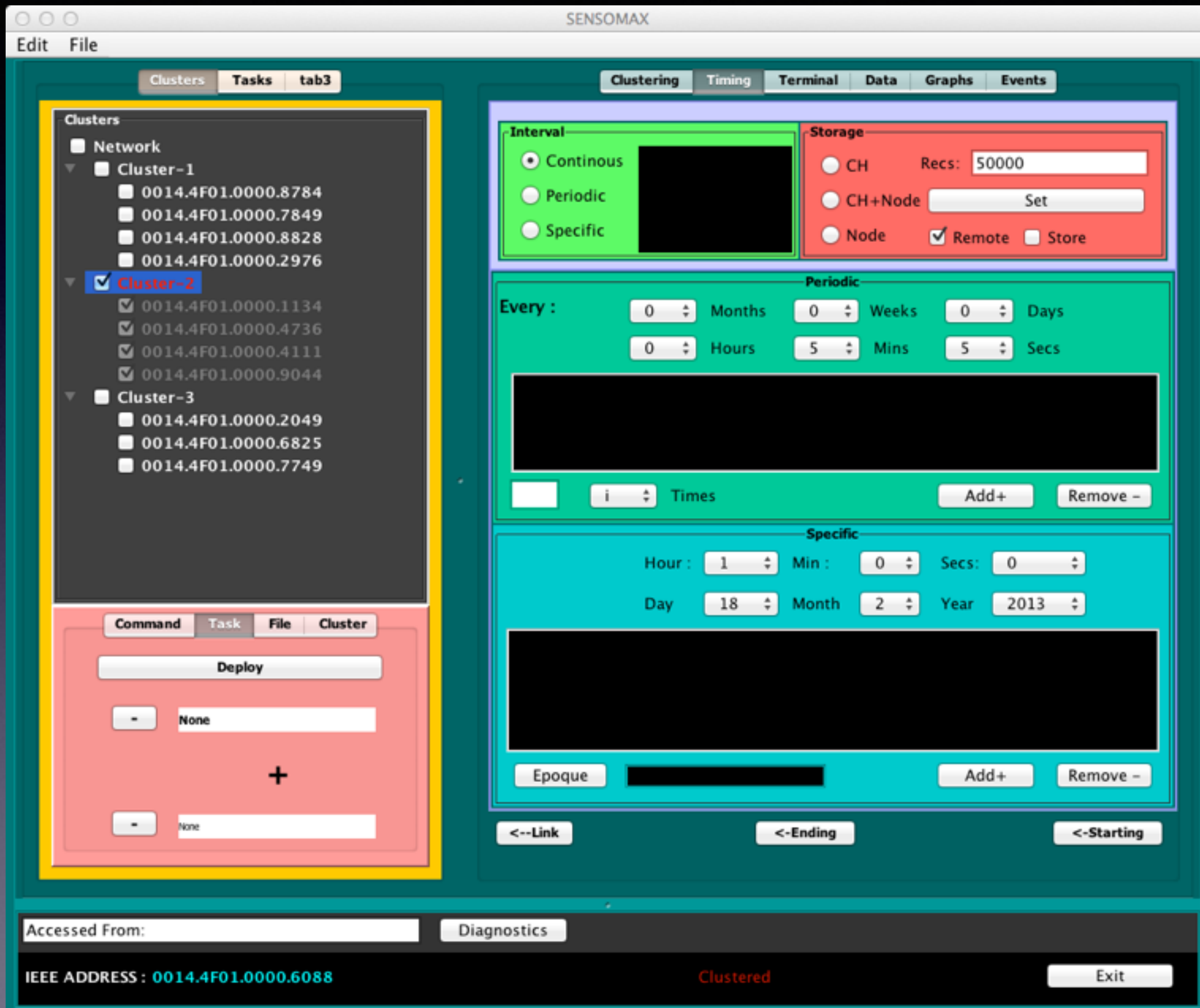
Concurrent Applications



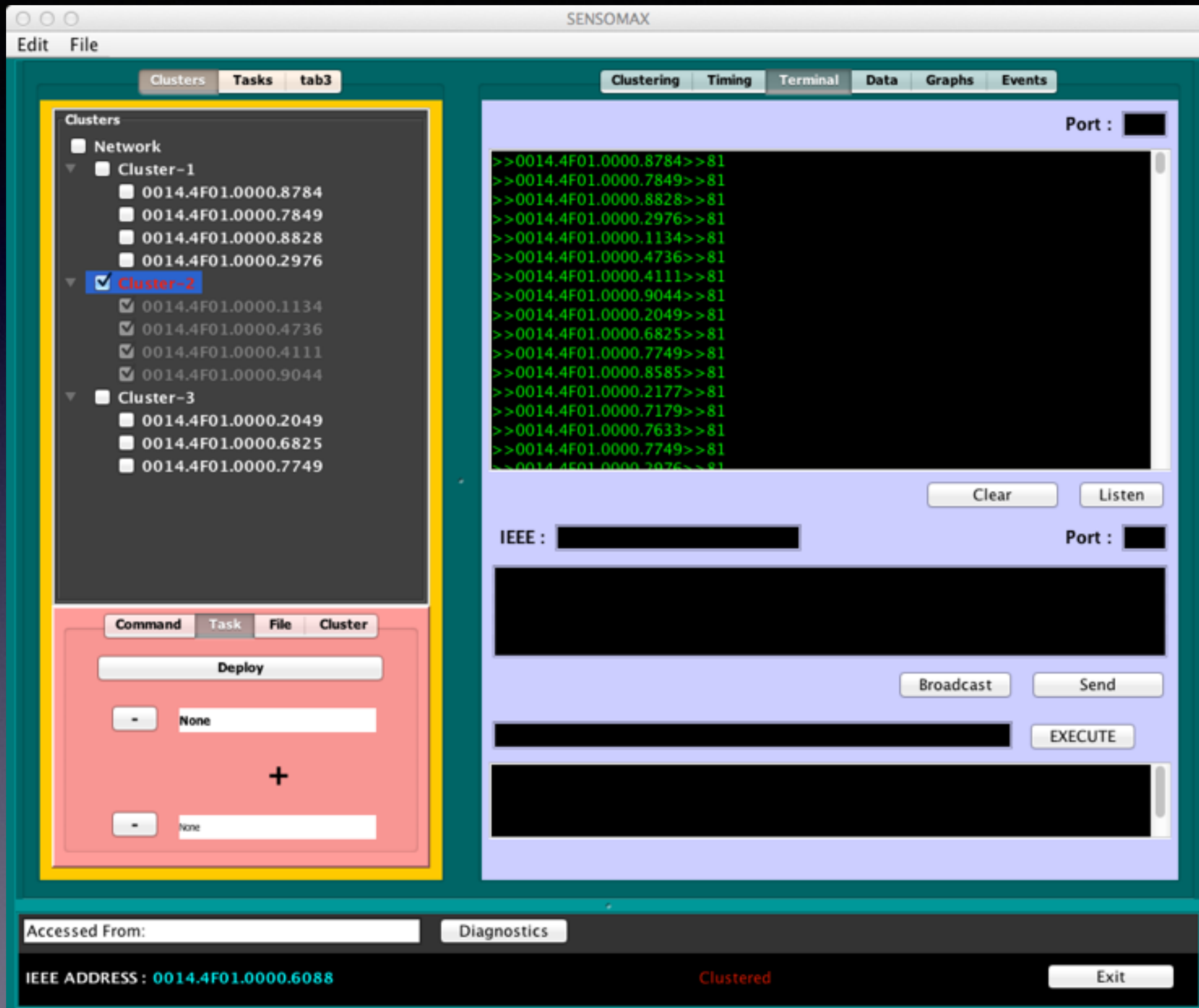
User Interface



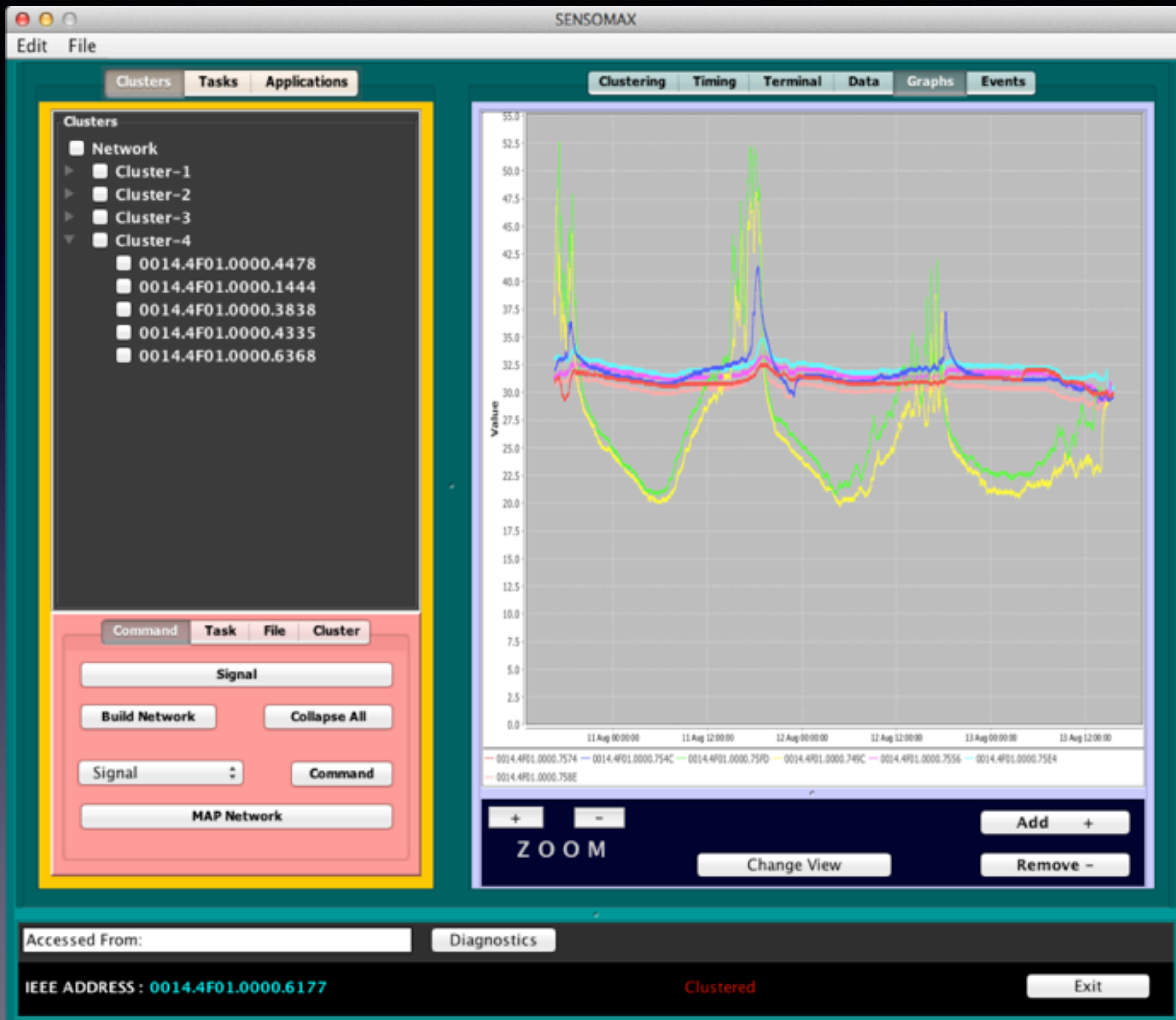
User Interface



User Interface



User Interface

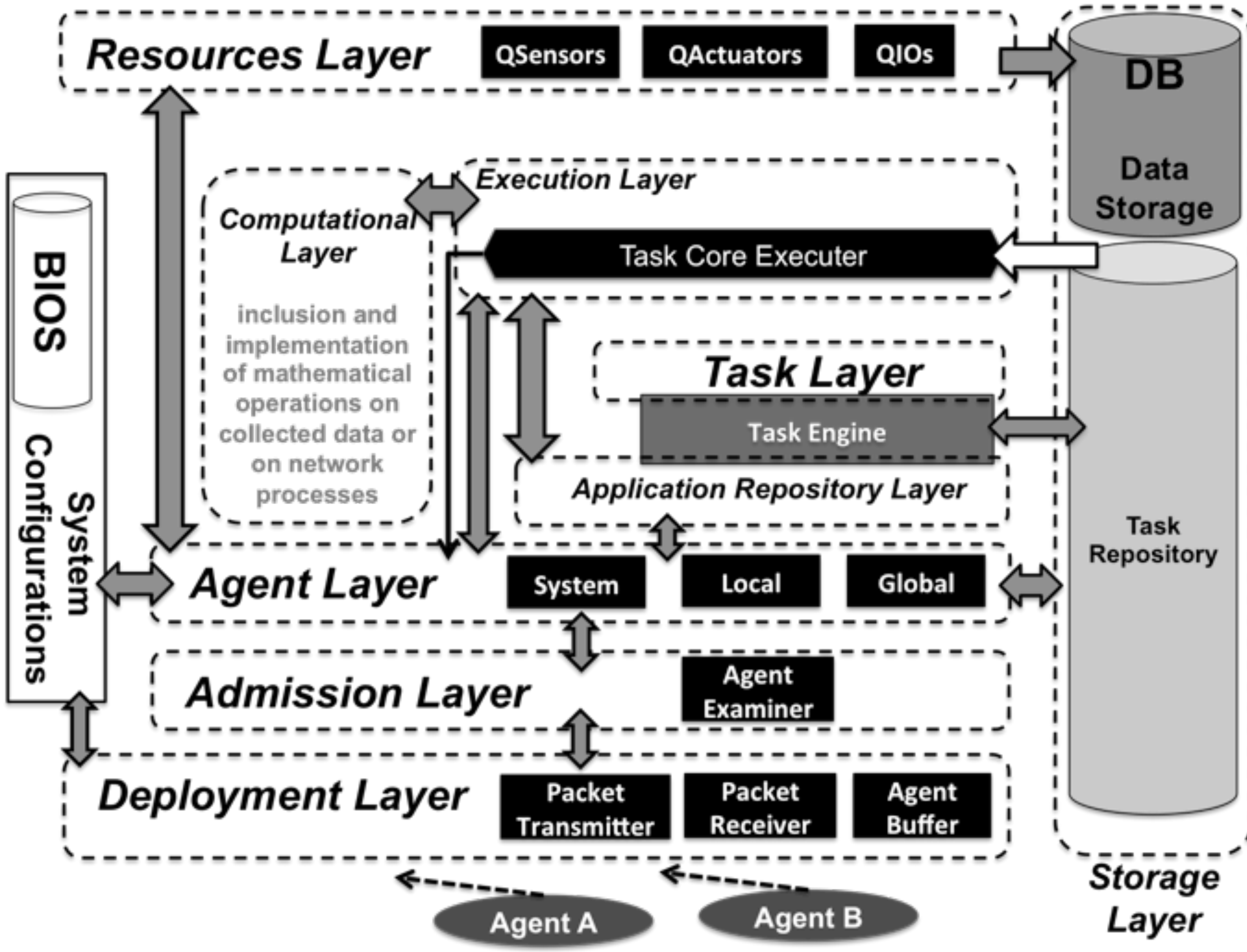


User Interface

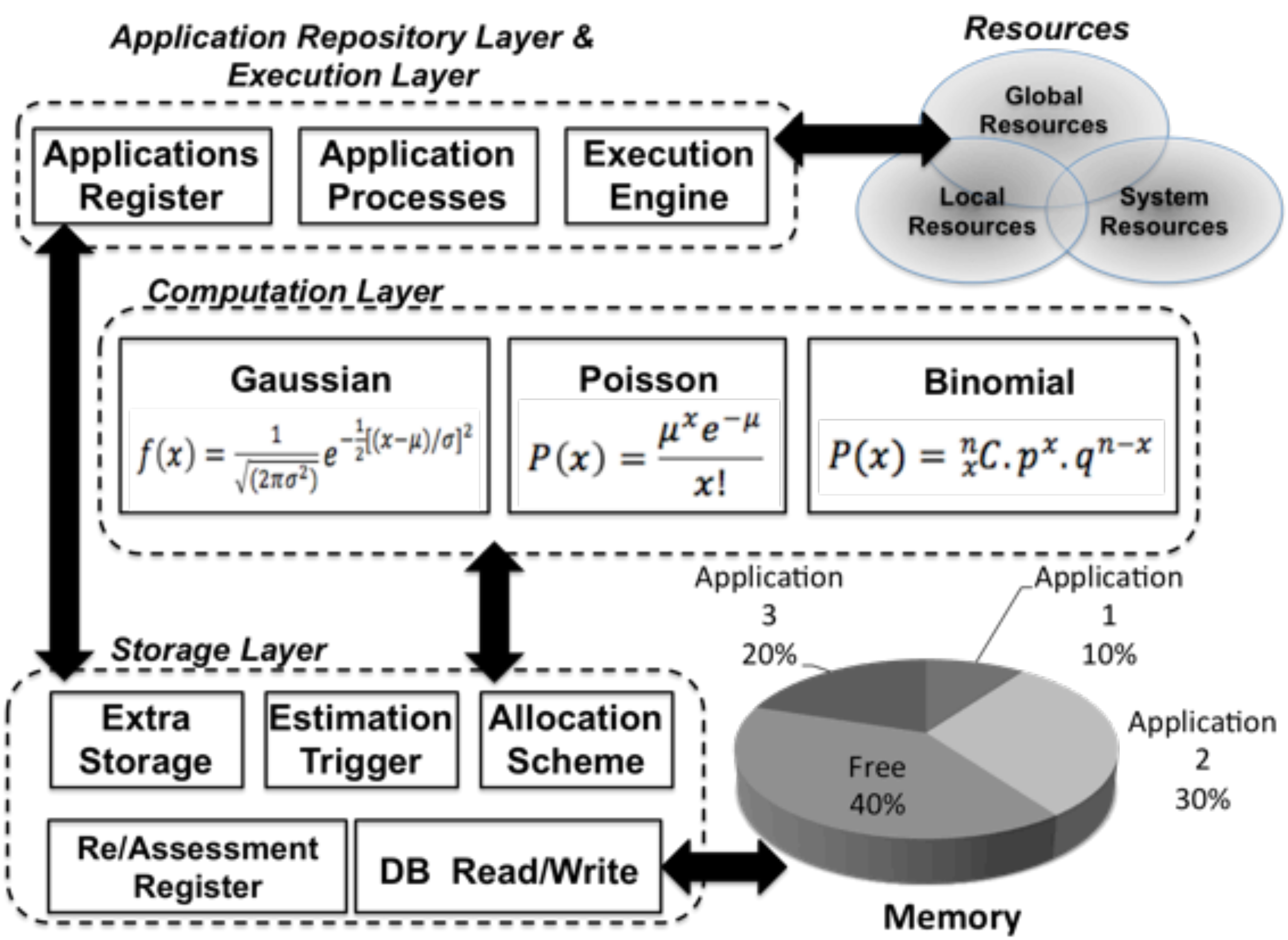
Summary

- *Decentralized operation/Task Execution*
- *Multi-Tasking Support*
- *Serving Multiple Applications*
- *Dynamic Operational Paradigm*
- *Customized Data-gathering*
- *Scalable via the internet*

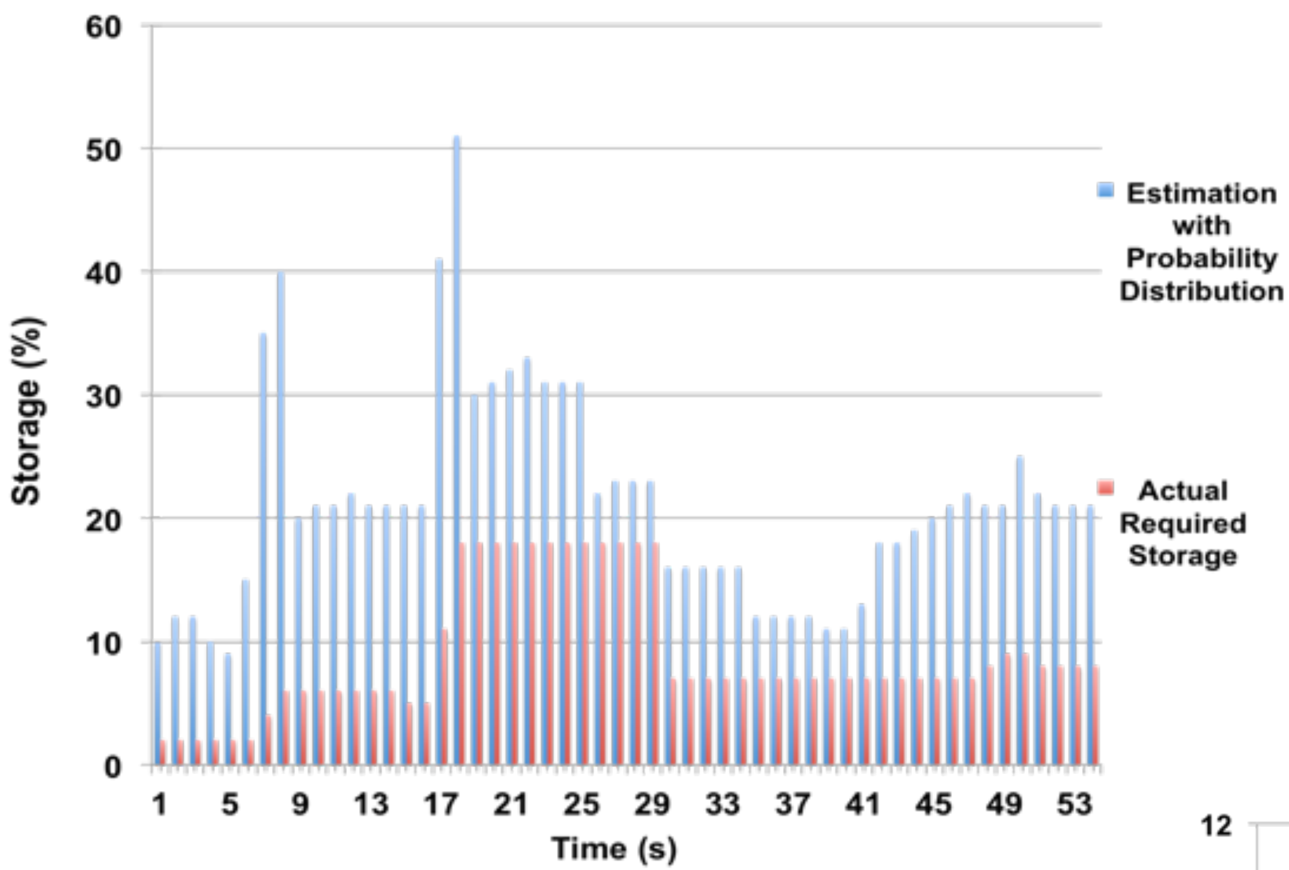
Computation

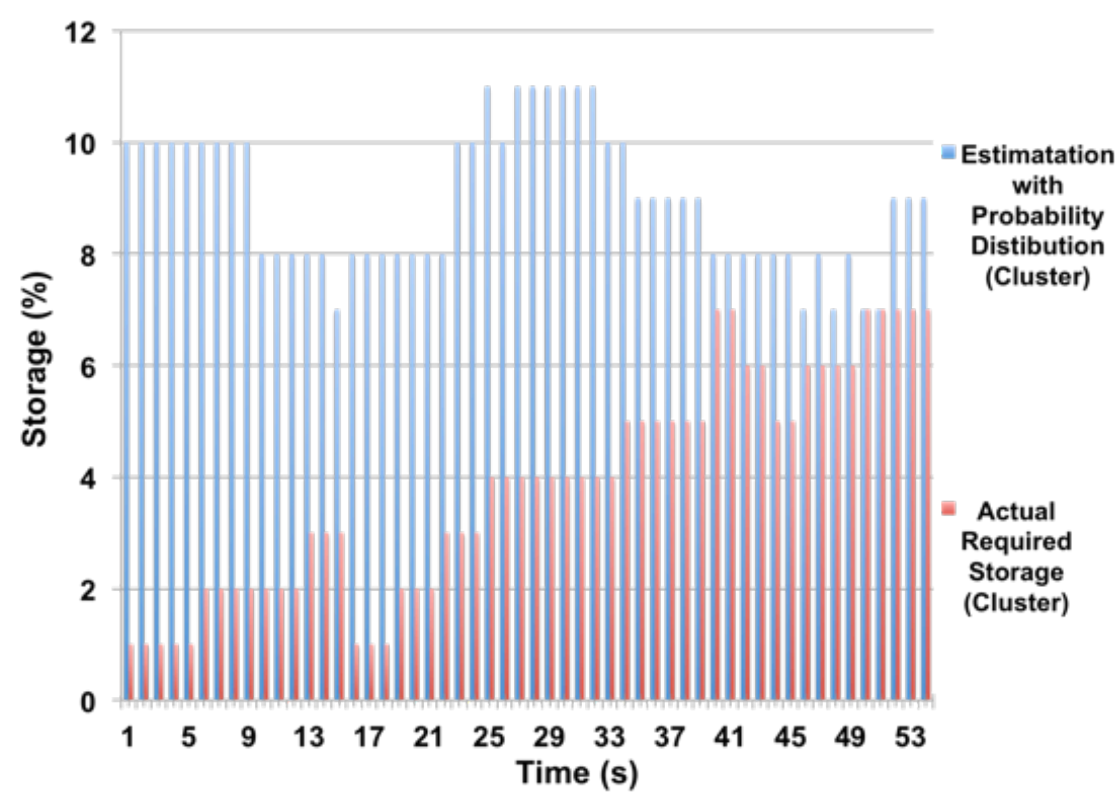


Storage Estimation



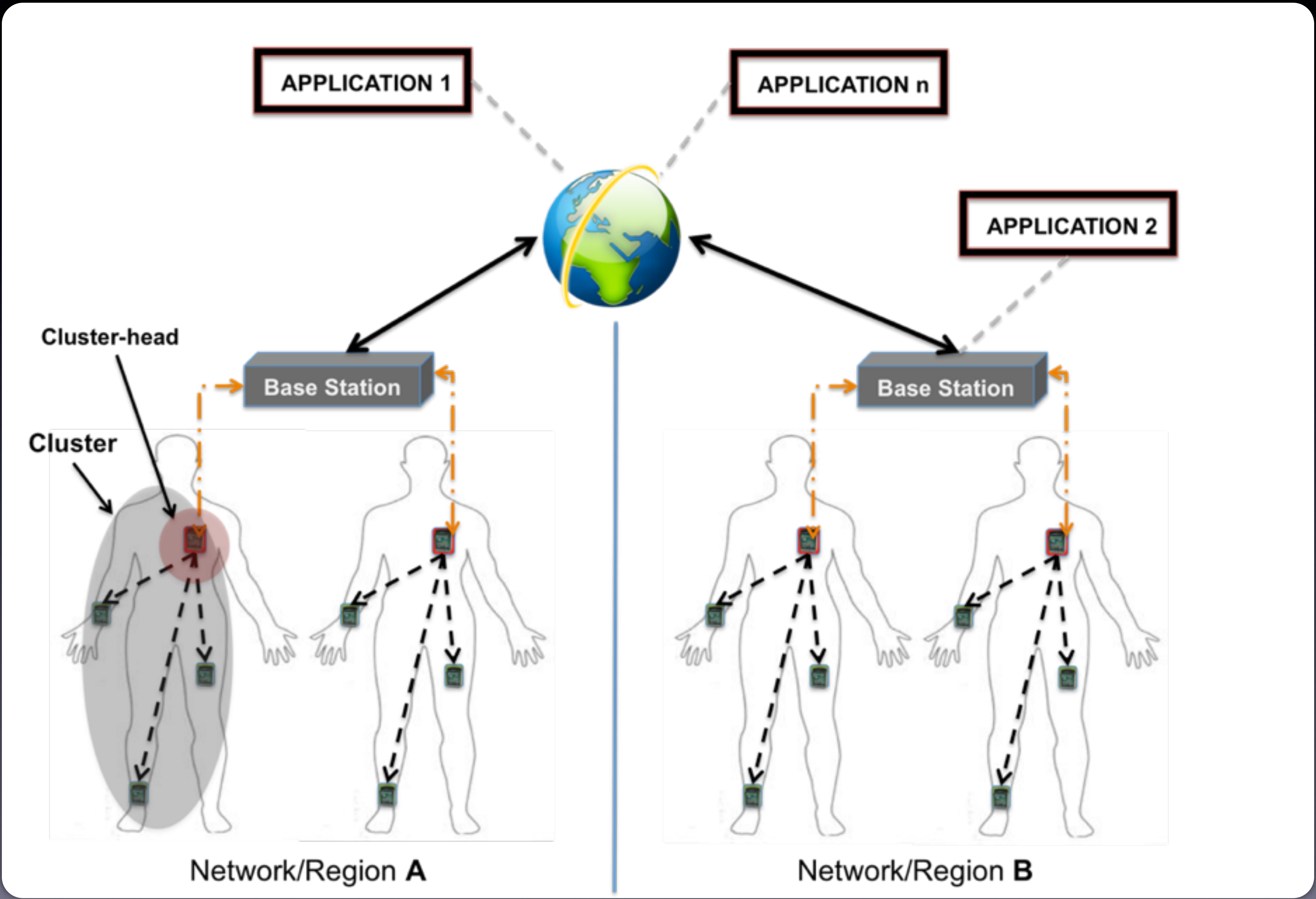
Storage Estimation

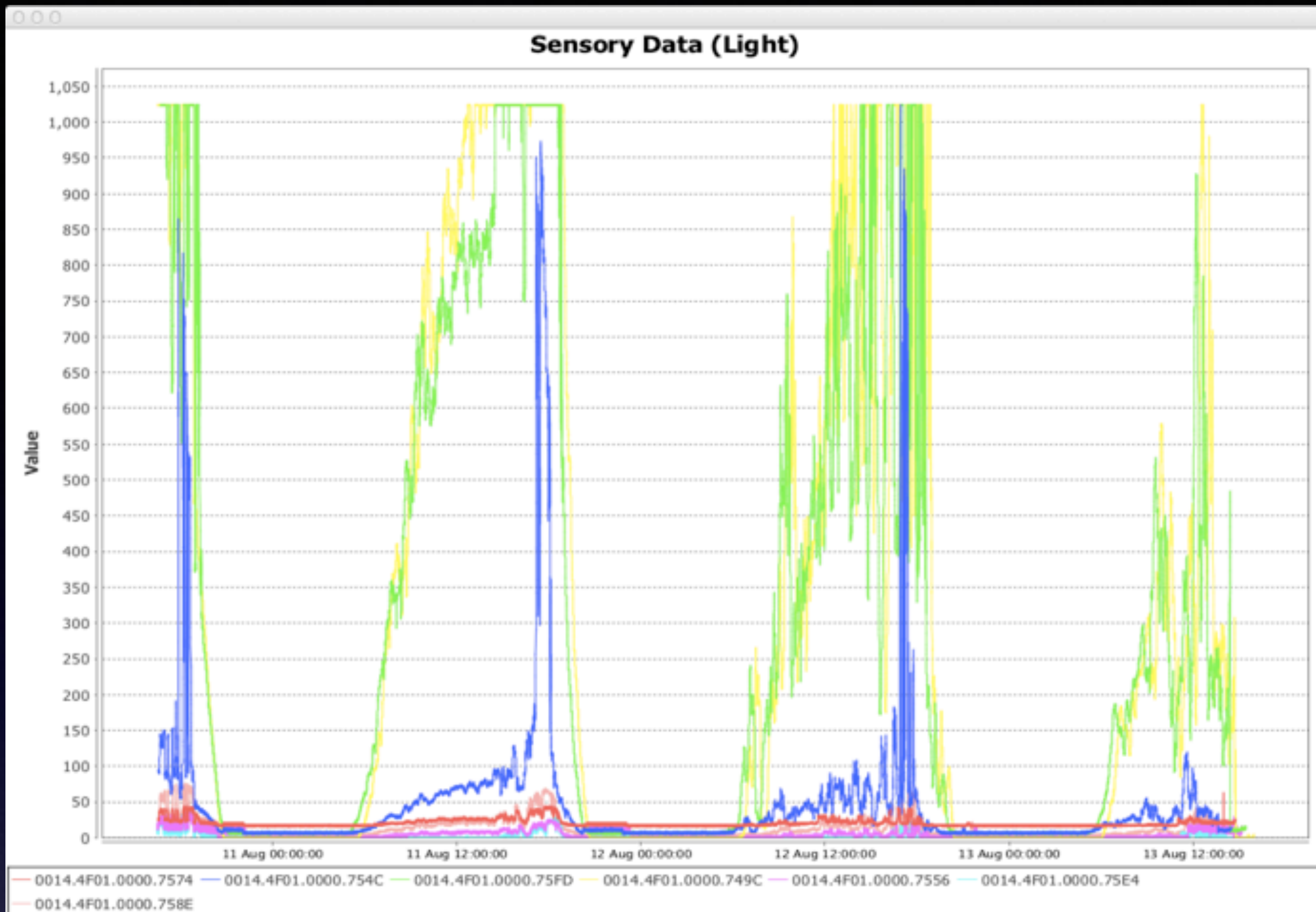




Detecting Anomalies in Data Streams

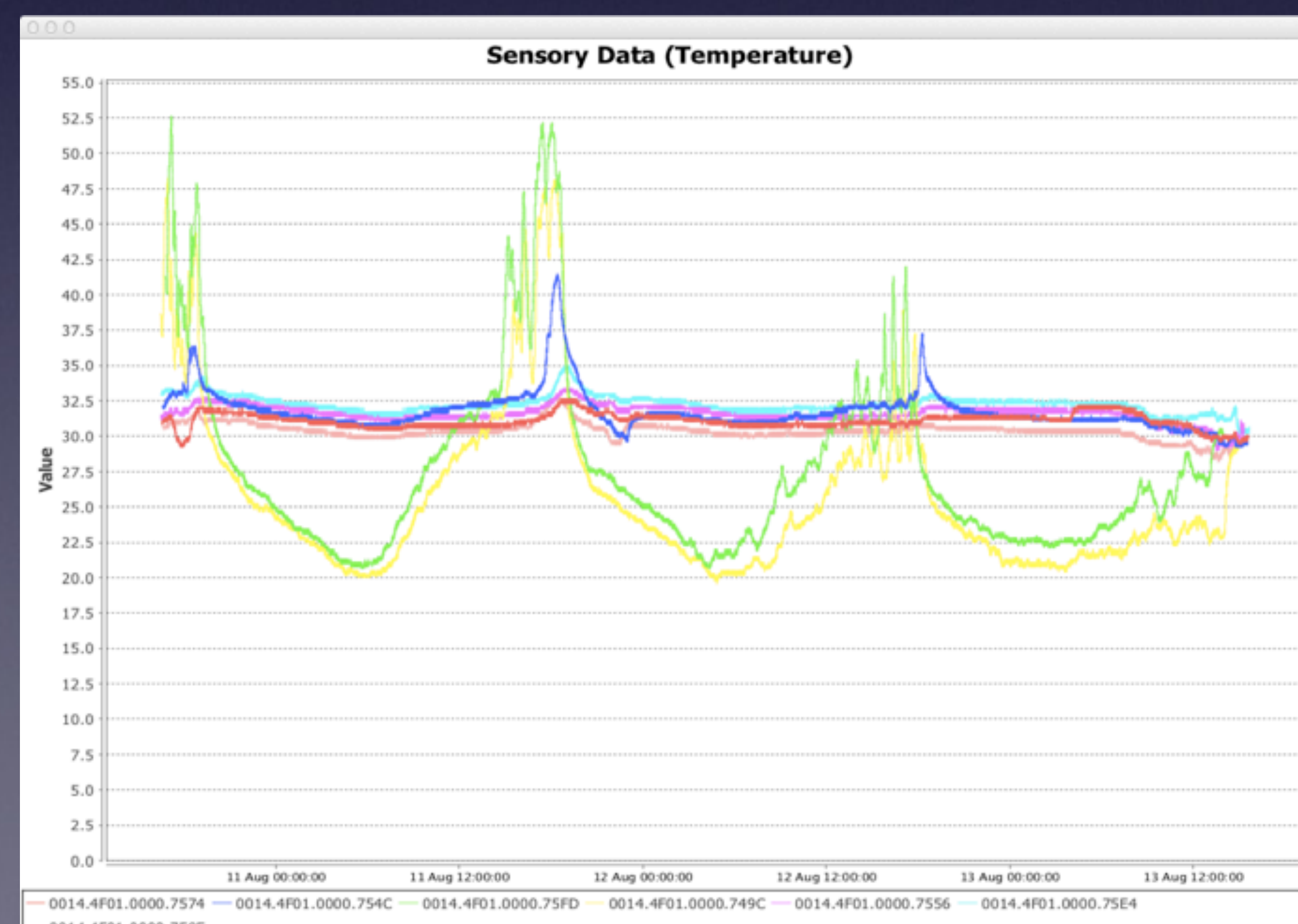
Concurrent Applications





Recording
Light and Temperature
for 36hrs

12 Sensors Storing
Light and Temperature
every10 second



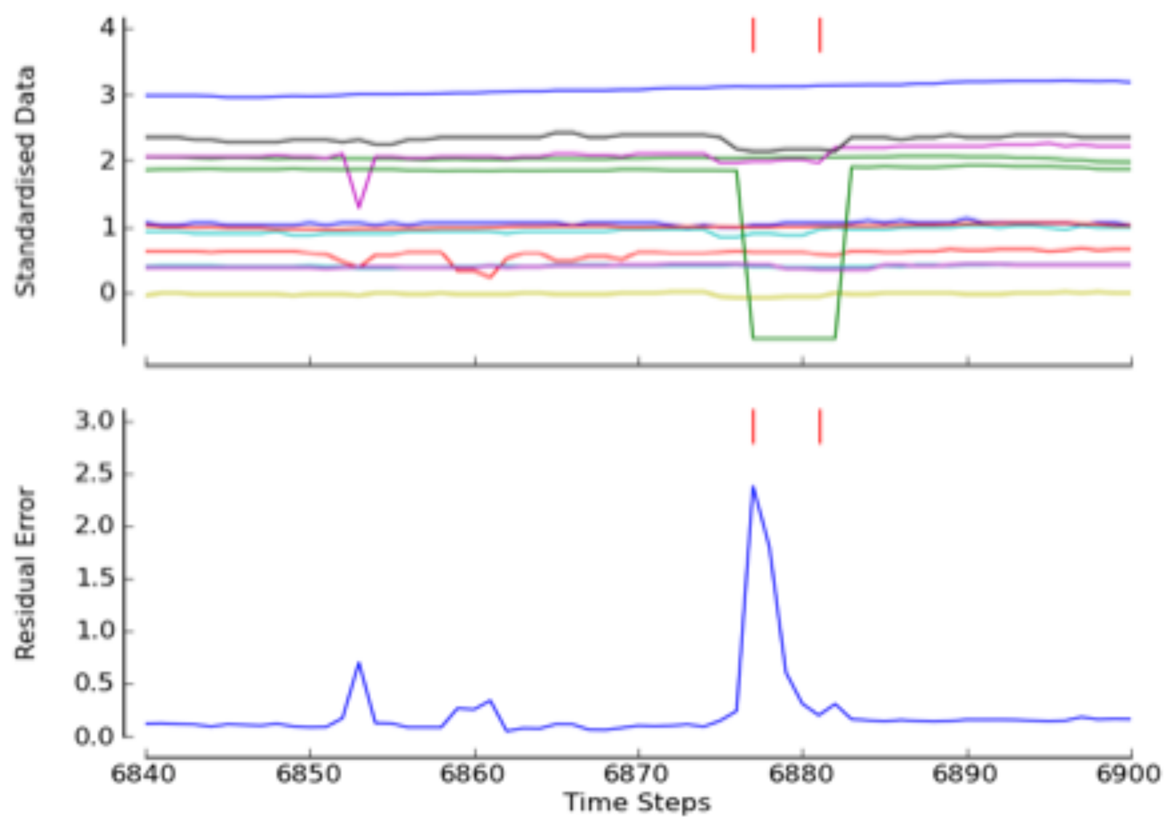
Change point Detecting Subspace Tracker (CD-ST)

An algorithm designed to monitor multiple data streams in parallel and addresses the problem of detecting significant change points or 'points of interest' in multiple data streams in an unsupervised setting.

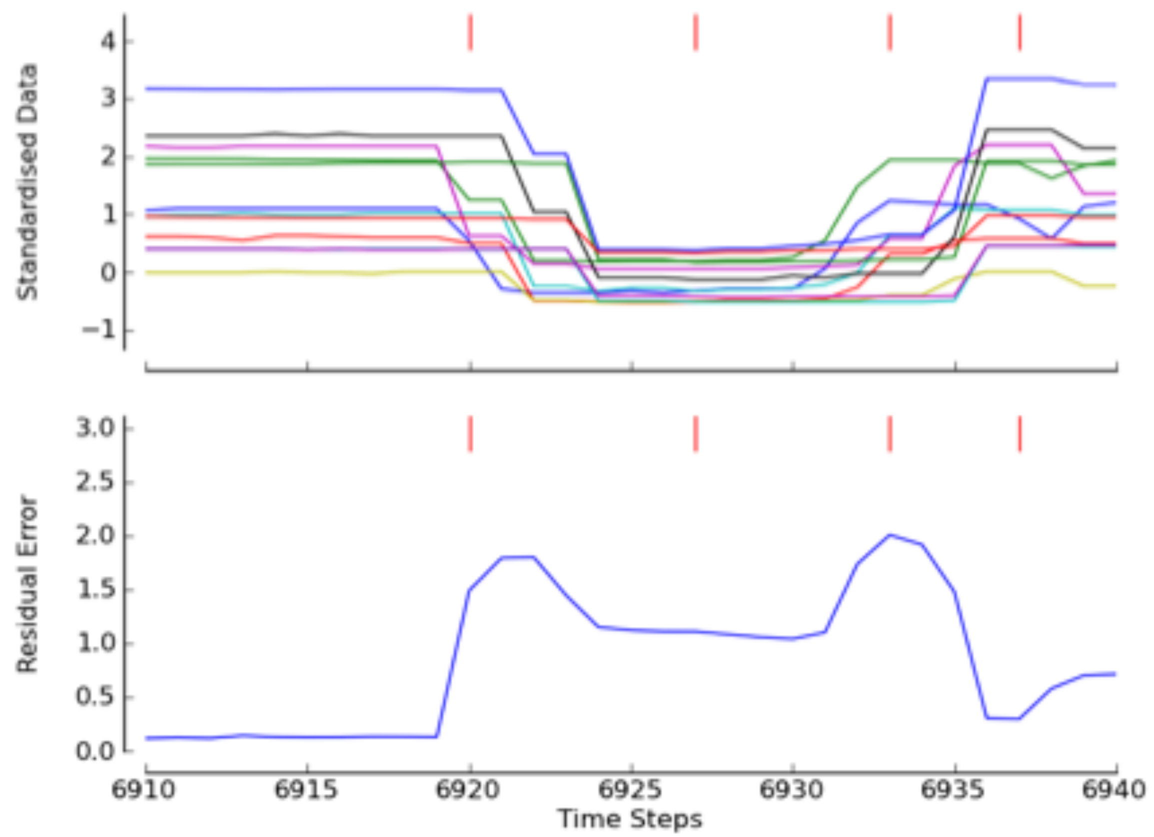
The algorithm uses dimensionality reduction to construct a reduced representation of the data (a subspace), which is then iteratively updated as new data points arrive.

A key property of the CD-ST algorithm is that the changes it detects are relative changes across all data streams, rather than separate changes based on each data streams individual history

Results

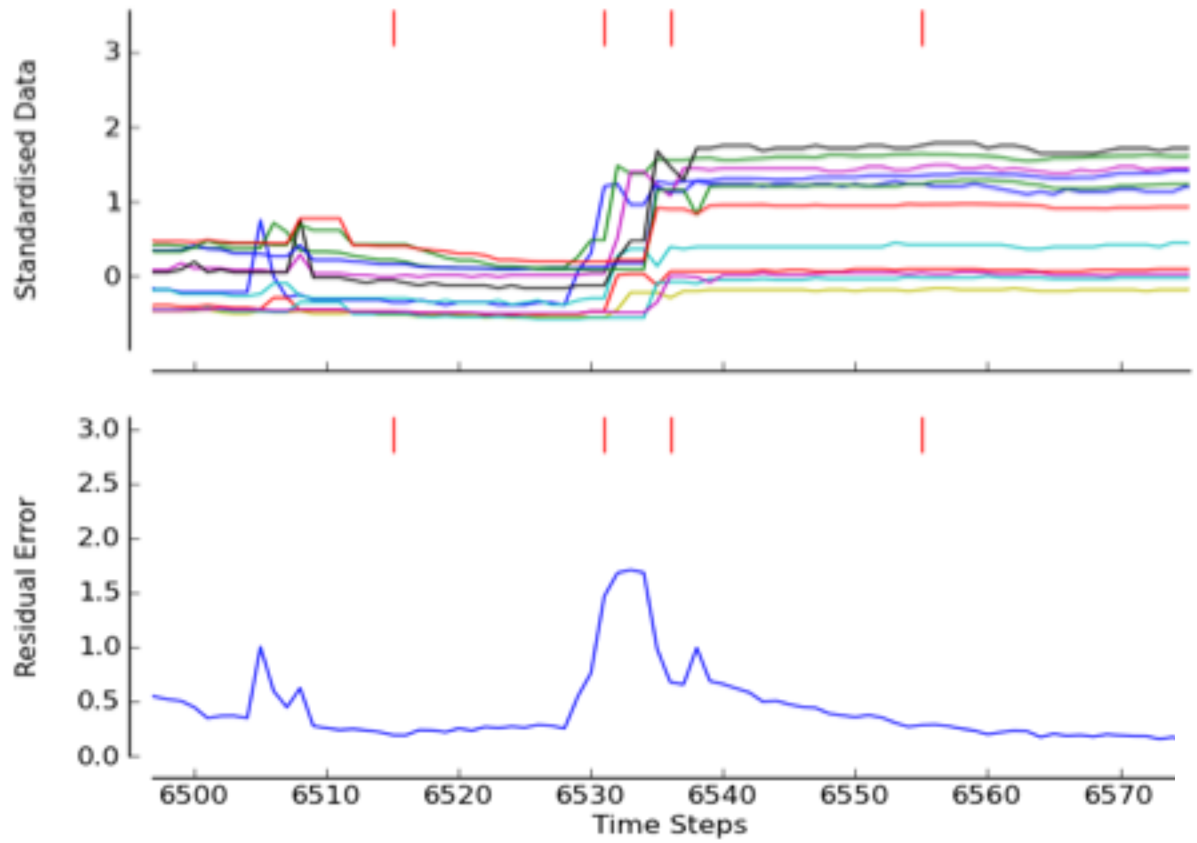


Single Sudden Change Point

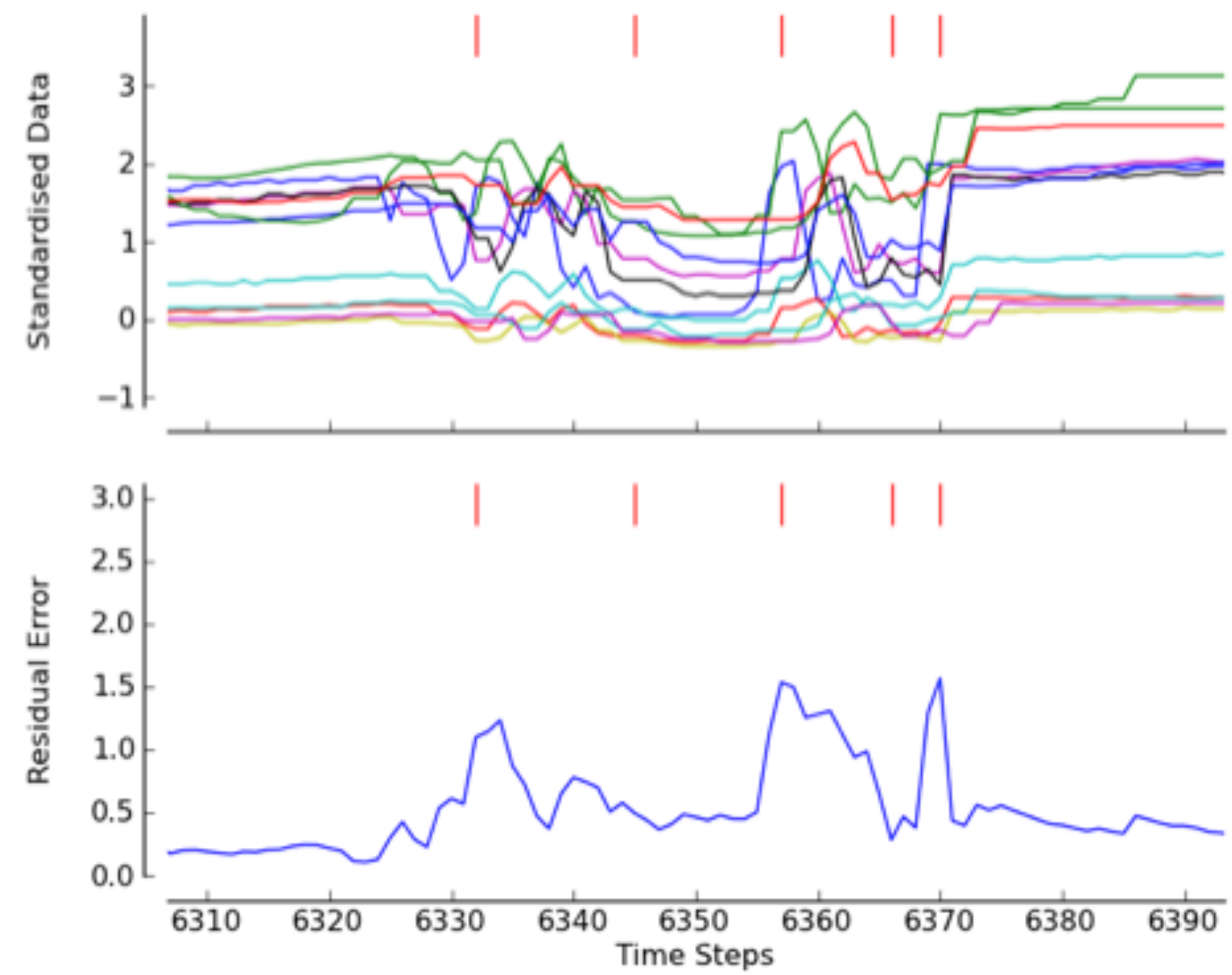


Multiple Simultaneous Change Points

Results



Non-recursive change points

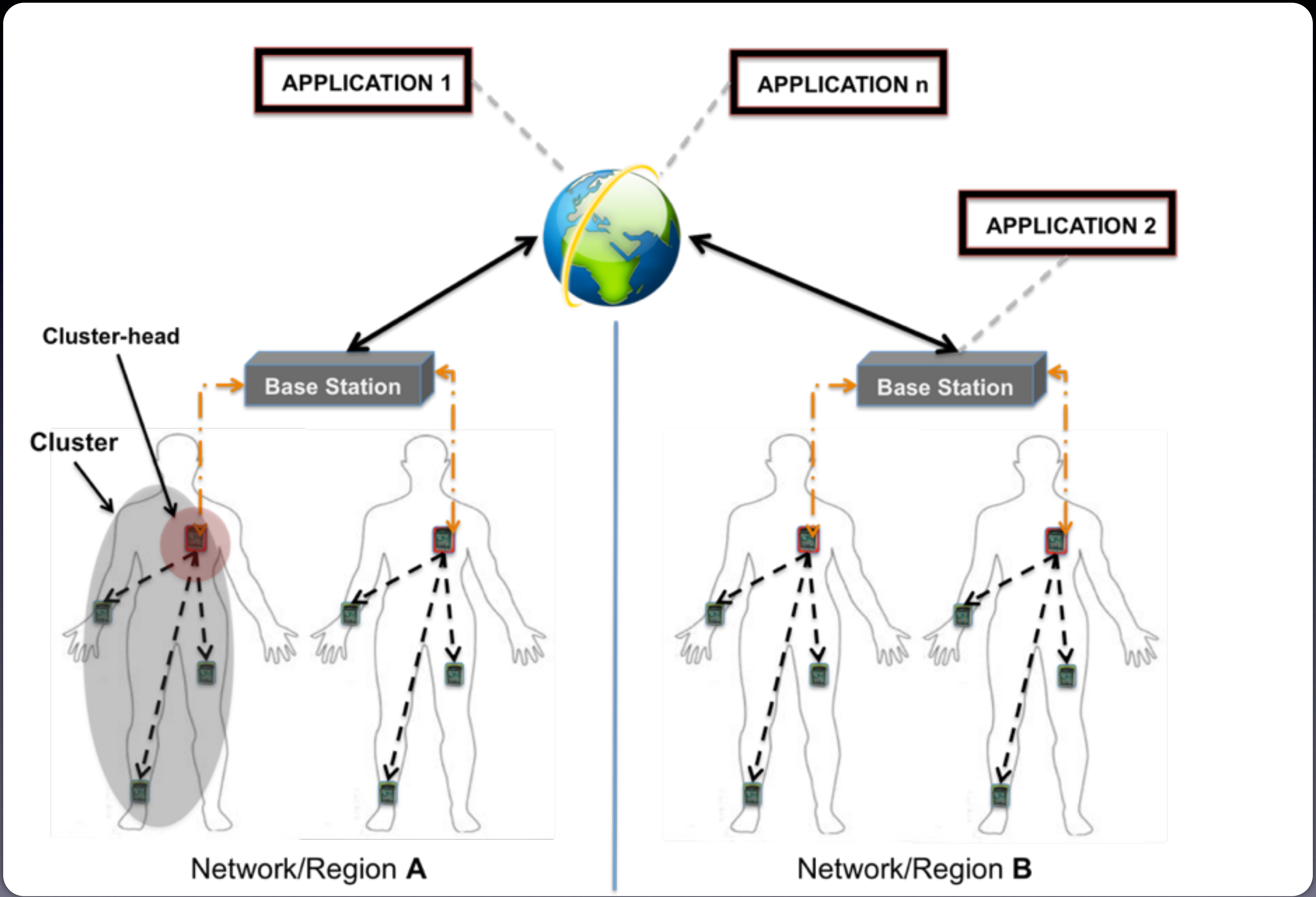


Recursive change points

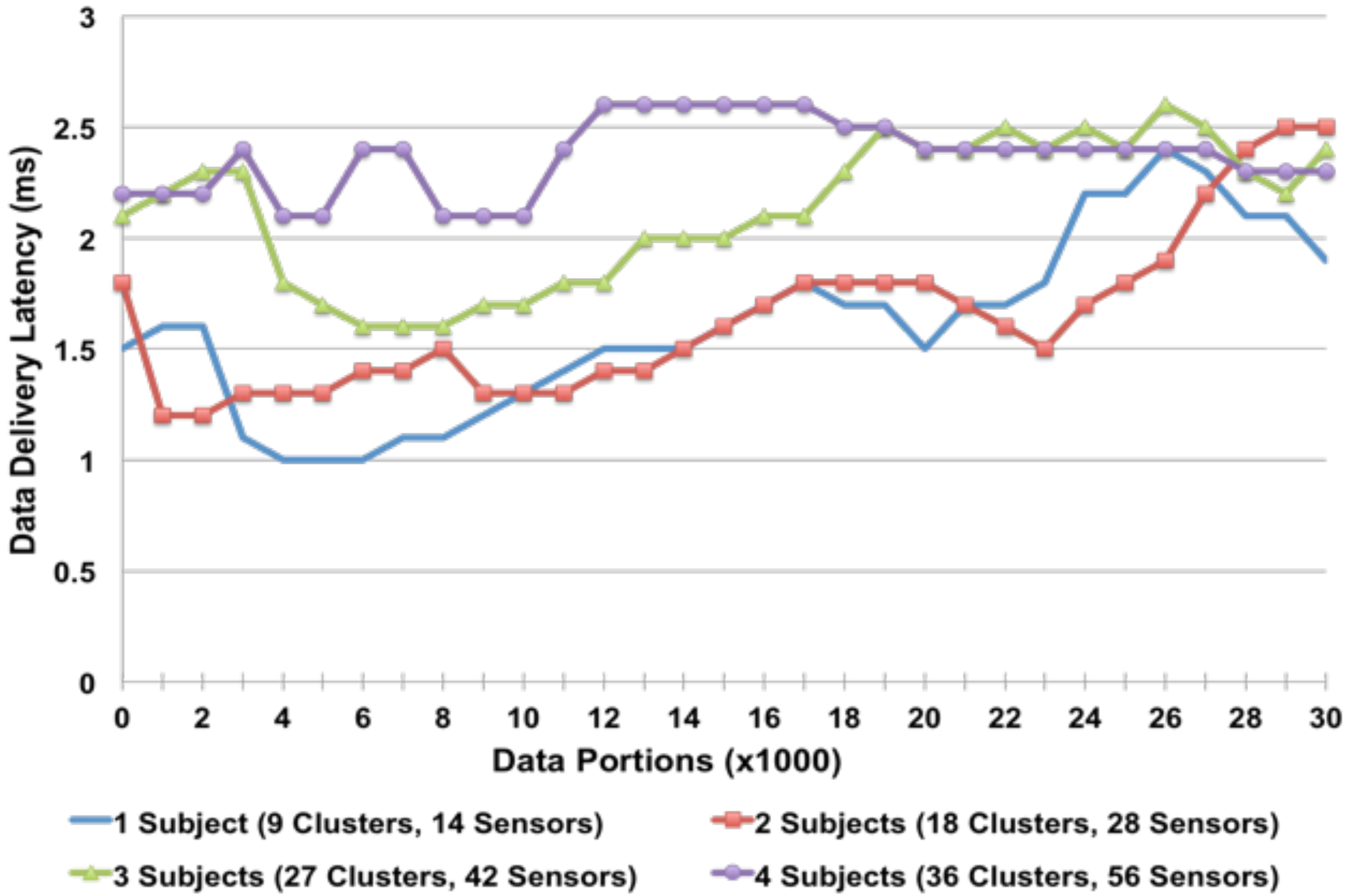
Health Monitoring

Segment	Definition
Upper arm*	Glenohumeral axis/Elbow axis
Forearm and hand*	Elbow axis/ulnar styloid
Thigh*	Greatertrochanter/femoral
Foot and leg*	Femoral condyles/medial
Trunk-head-neck	Greater trochanter/glenohumeral

Concurrent Applications



Synchronisation



Dynamic Data Storage Estimation

for

Multiple Concurrent Applications

using

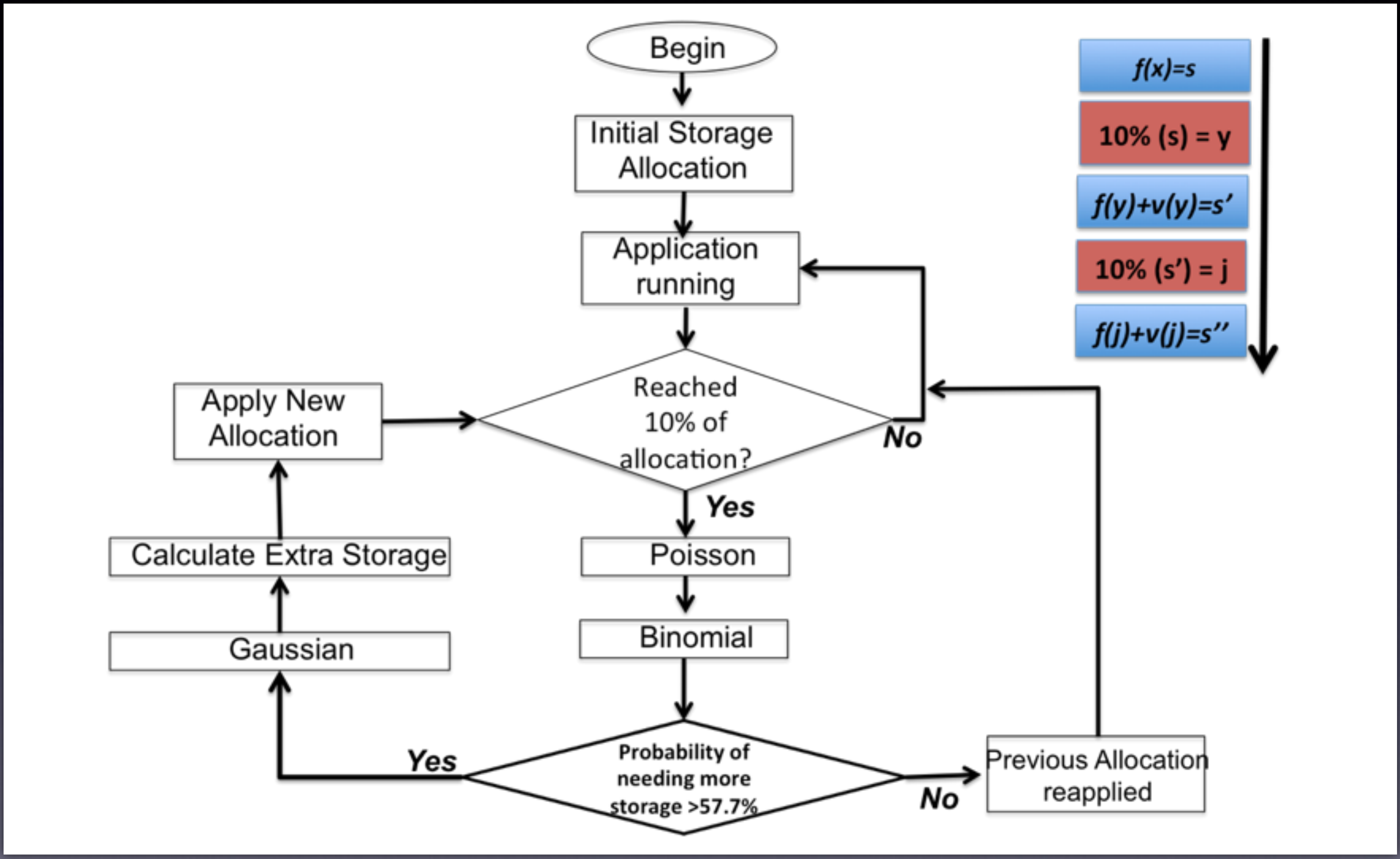
Probability Distribution Modelling

in WSNs

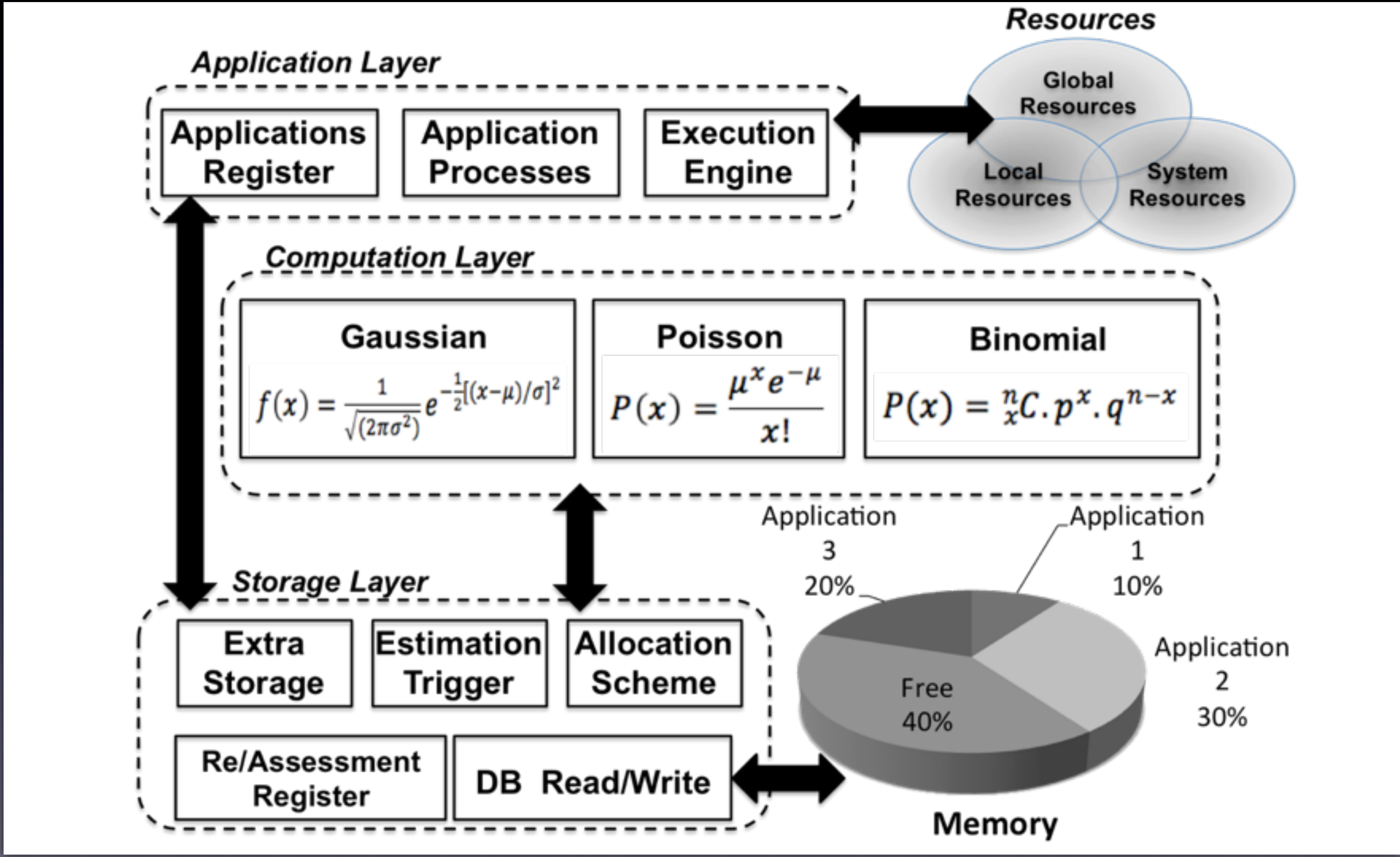
Objectives

- **Decentralized data storage estimation for each application locally by each node (Local Storage)**
- **Exploiting popular statistical data analysis that are easy to implement using Java and do not impose high footprint on resources.**
- **Facilitating more efficient data storage estimation for cluster-heads by breaking down the job among the members. (Cooperative Storage)**
- **Revalidating the allocated storage periodically to meet the application demands dynamically.**

Methodology

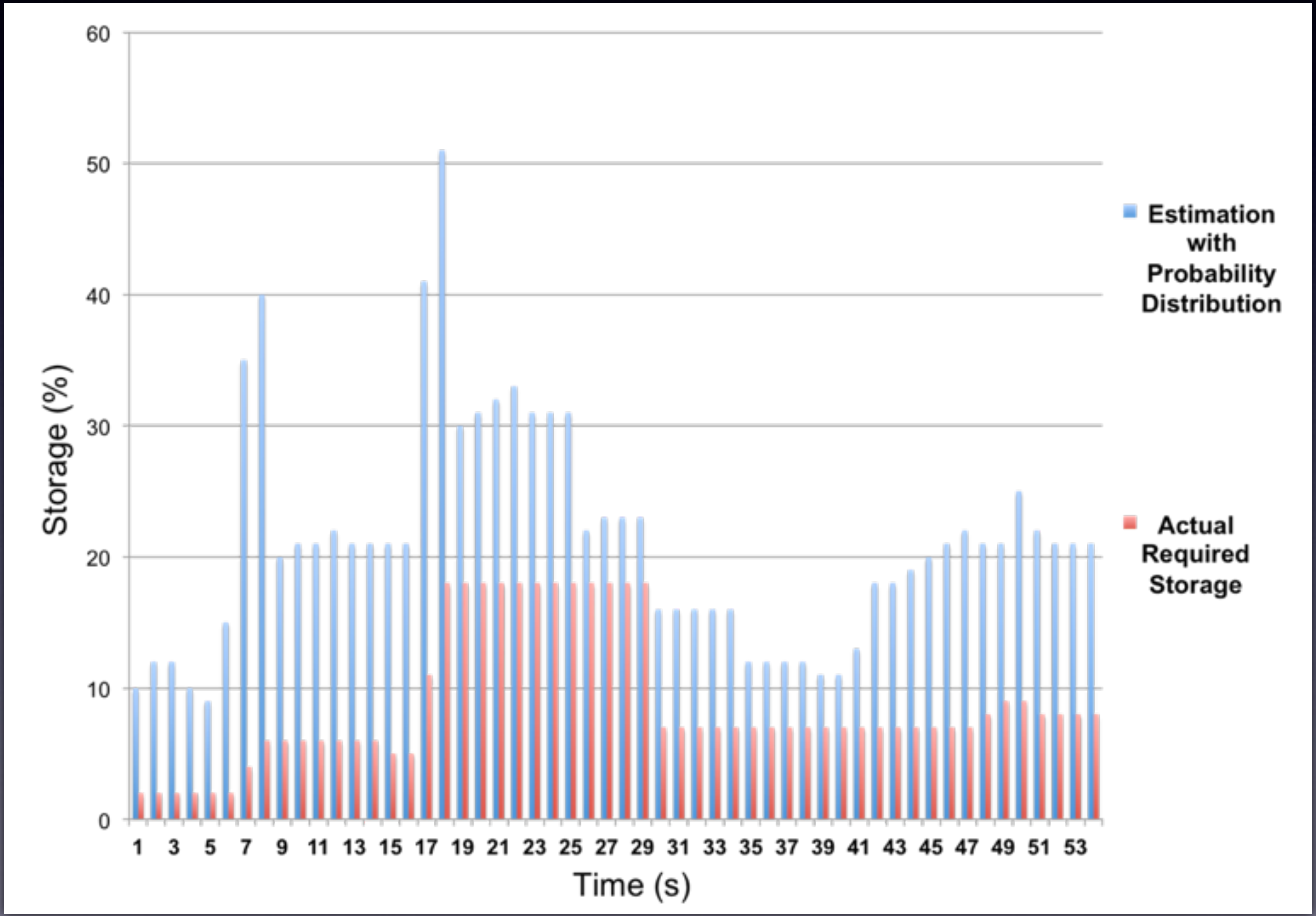


Methodology



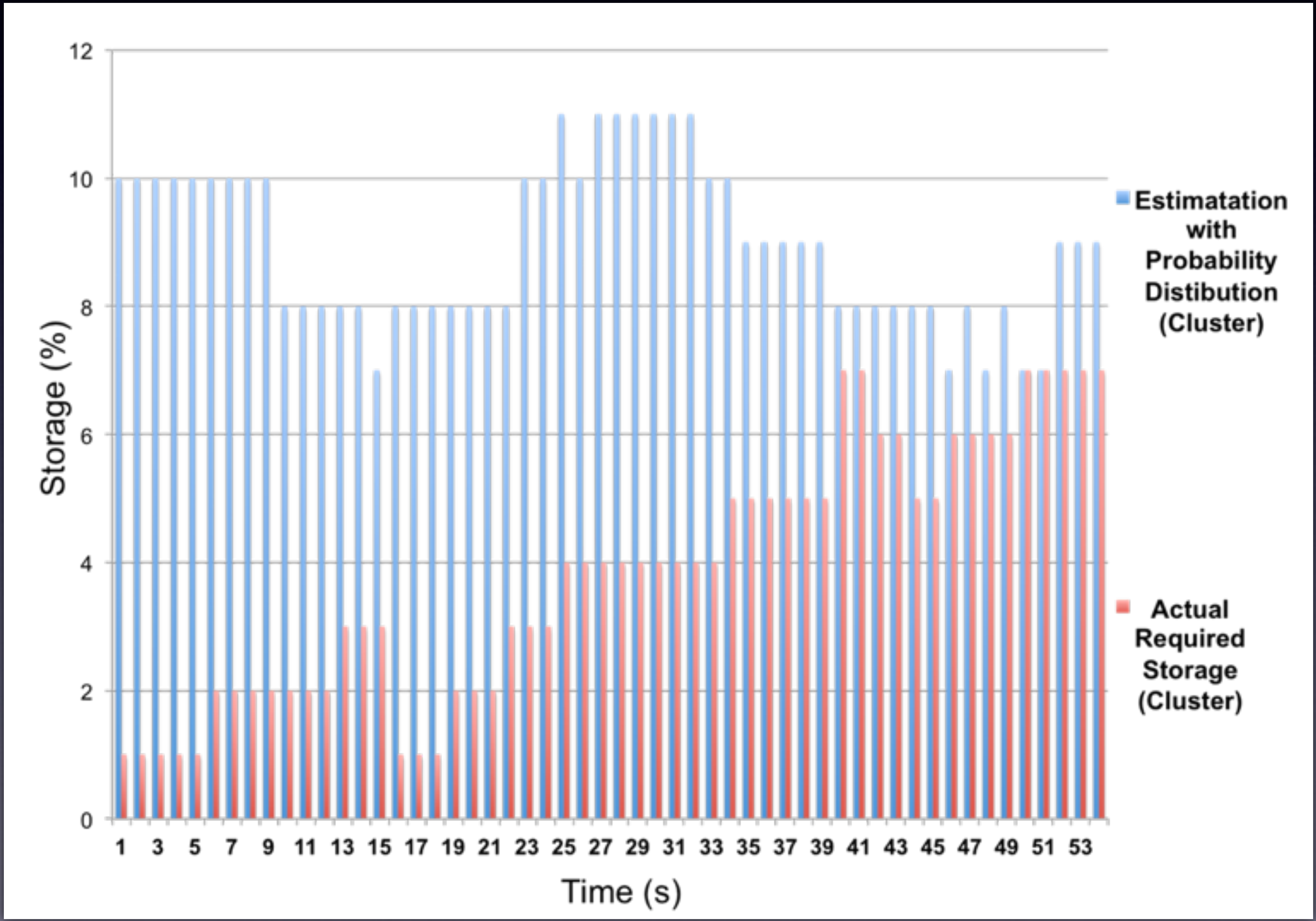
Benchmarking

Node-level Estimation Accuracy



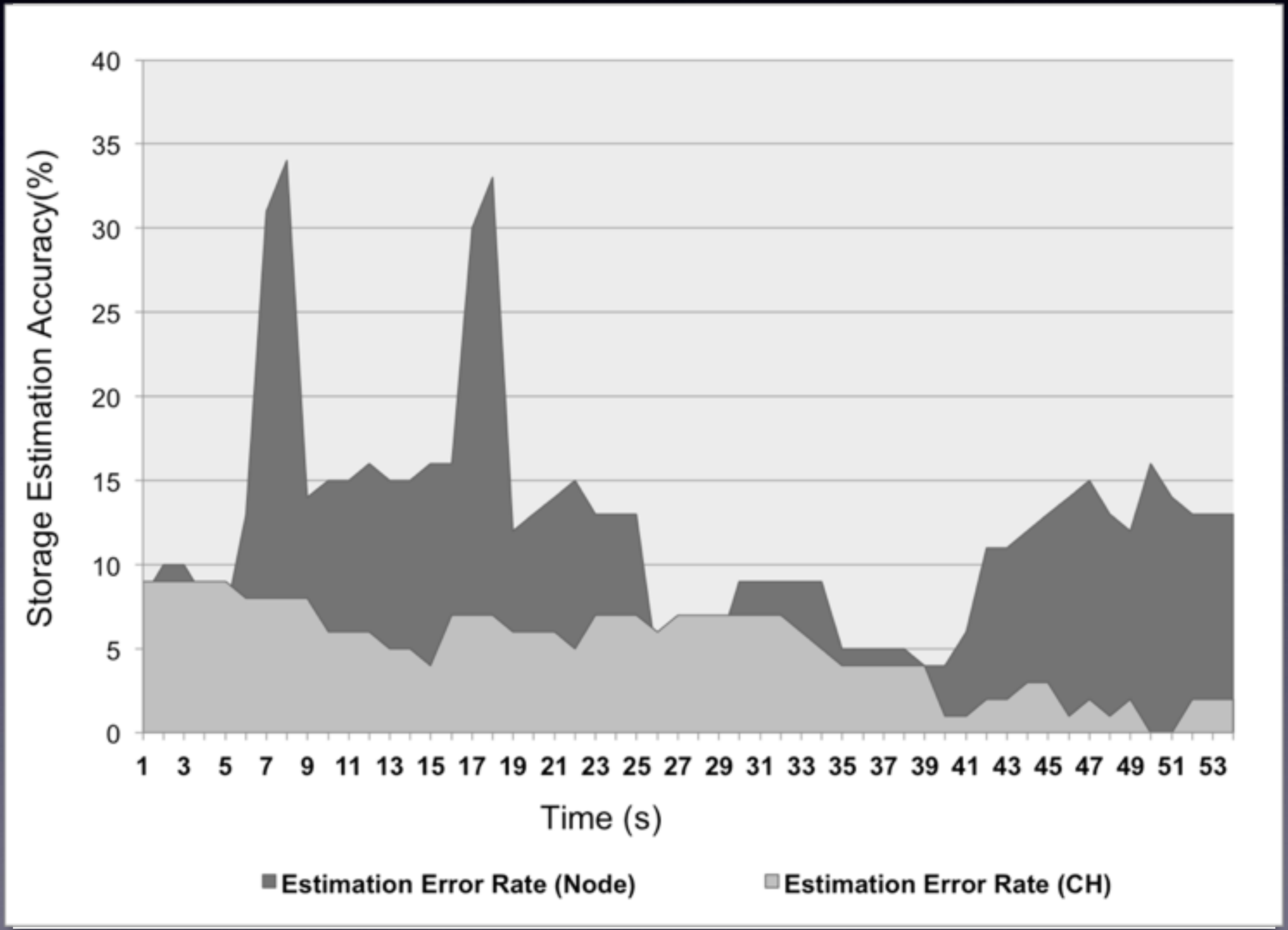
Benchmarking

Cluster-head Estimation Accuracy



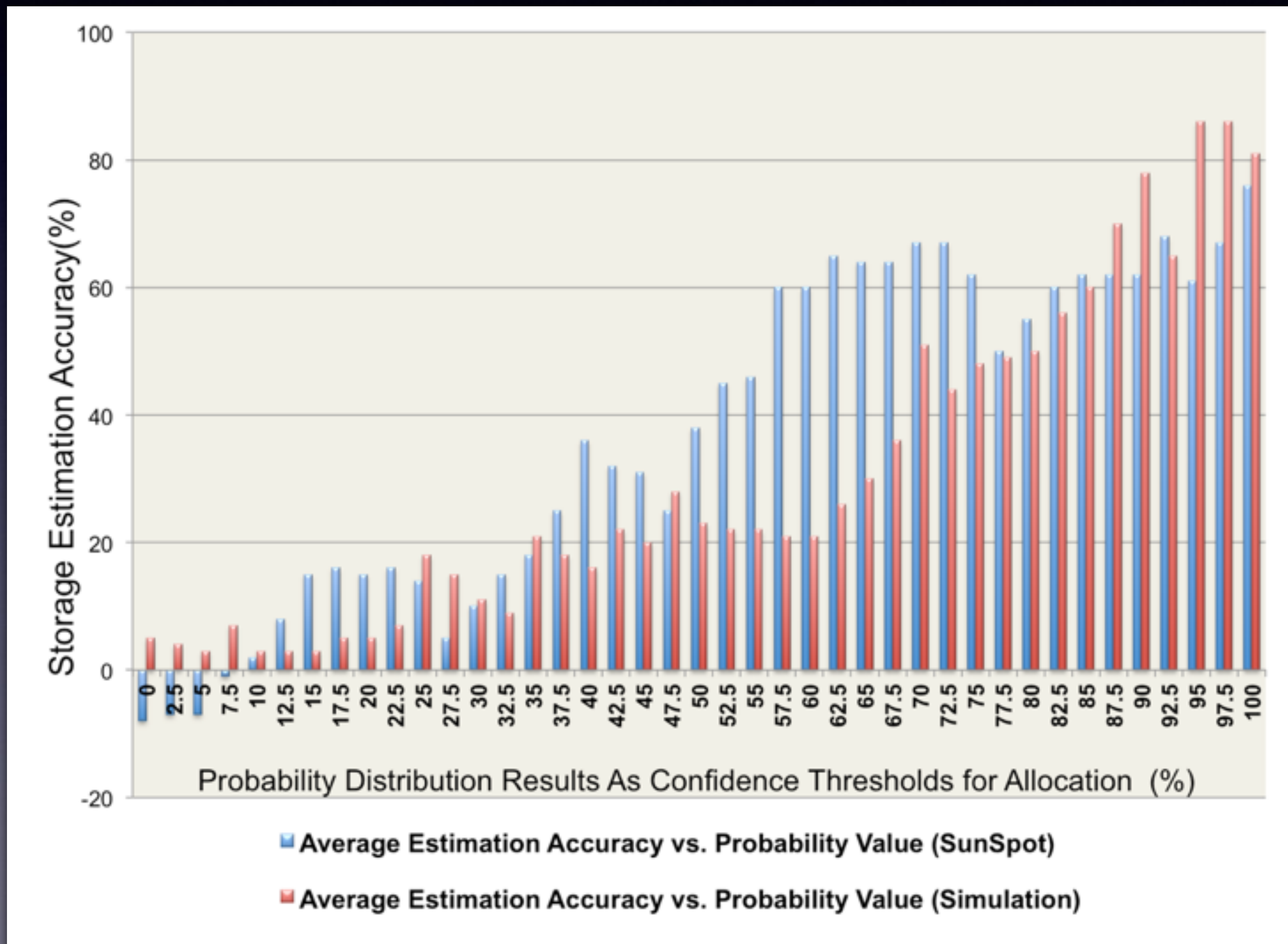
Benchmarking

Total Estimation Error Rate



Benchmarking

Confidence Values vs. Accuracy



Large-scale Simulation?

- ***Memory Constraints***
- ***Lack of Concurrency-Modeling***
- ***No Support for Cloud-based Interaction***

Large-scale Simulation?

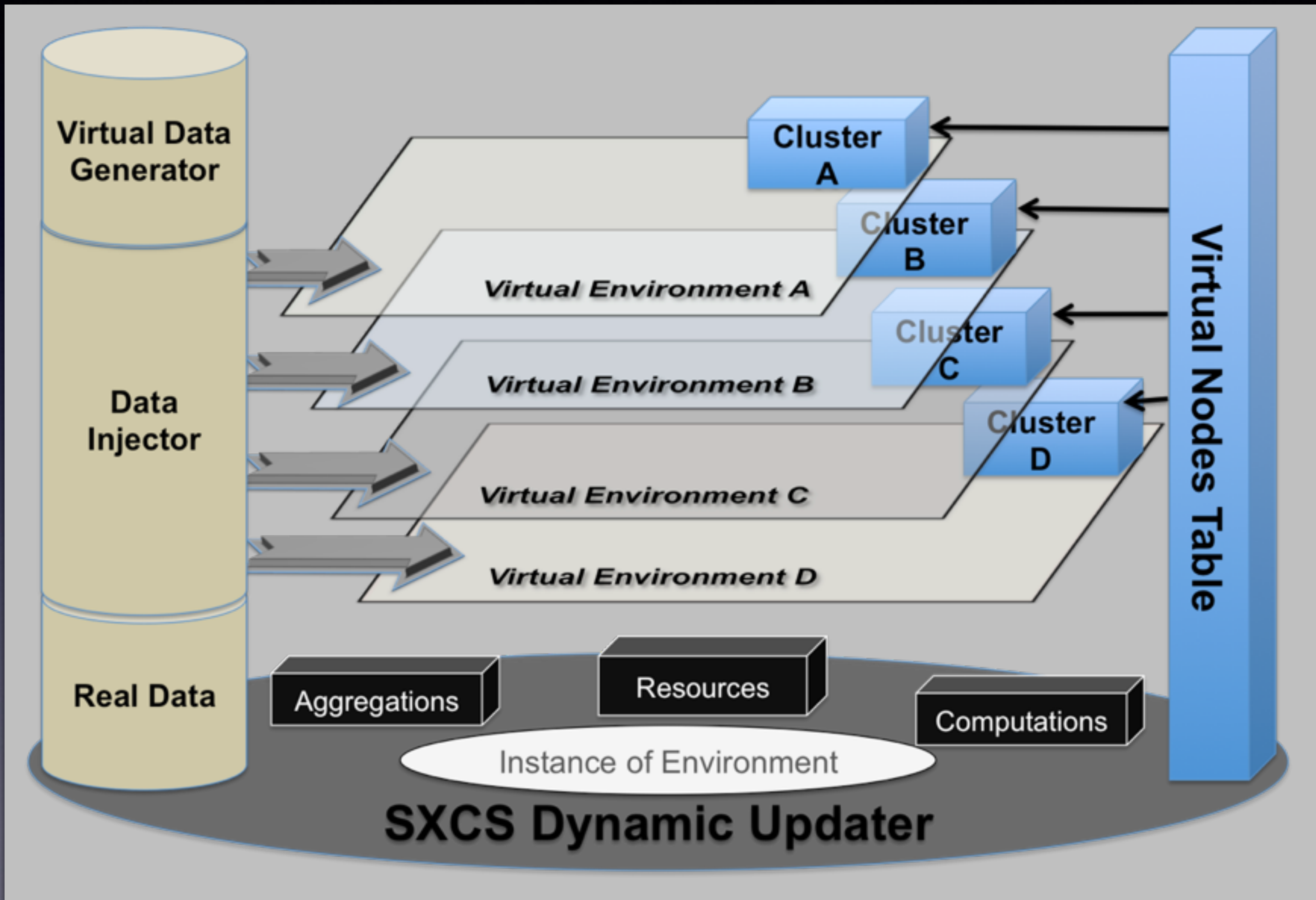
Sensomax Companion Simulator

SXCS

SXCS

1) **Thread-based and FSM-based combined operation**
2) **Common communication protocols: TCP/IP, UDP**
3) **Command line and graphical user interfaces**
4) **Object-oriented deep modular nesting**
5) **Debugging tools for displaying components interactions**
6) **Interoperability for various platforms**
7) **Direct and indirect components interactions**
8) **Virtualizing up to 2500 instances (virtual nodes)**

SXCS

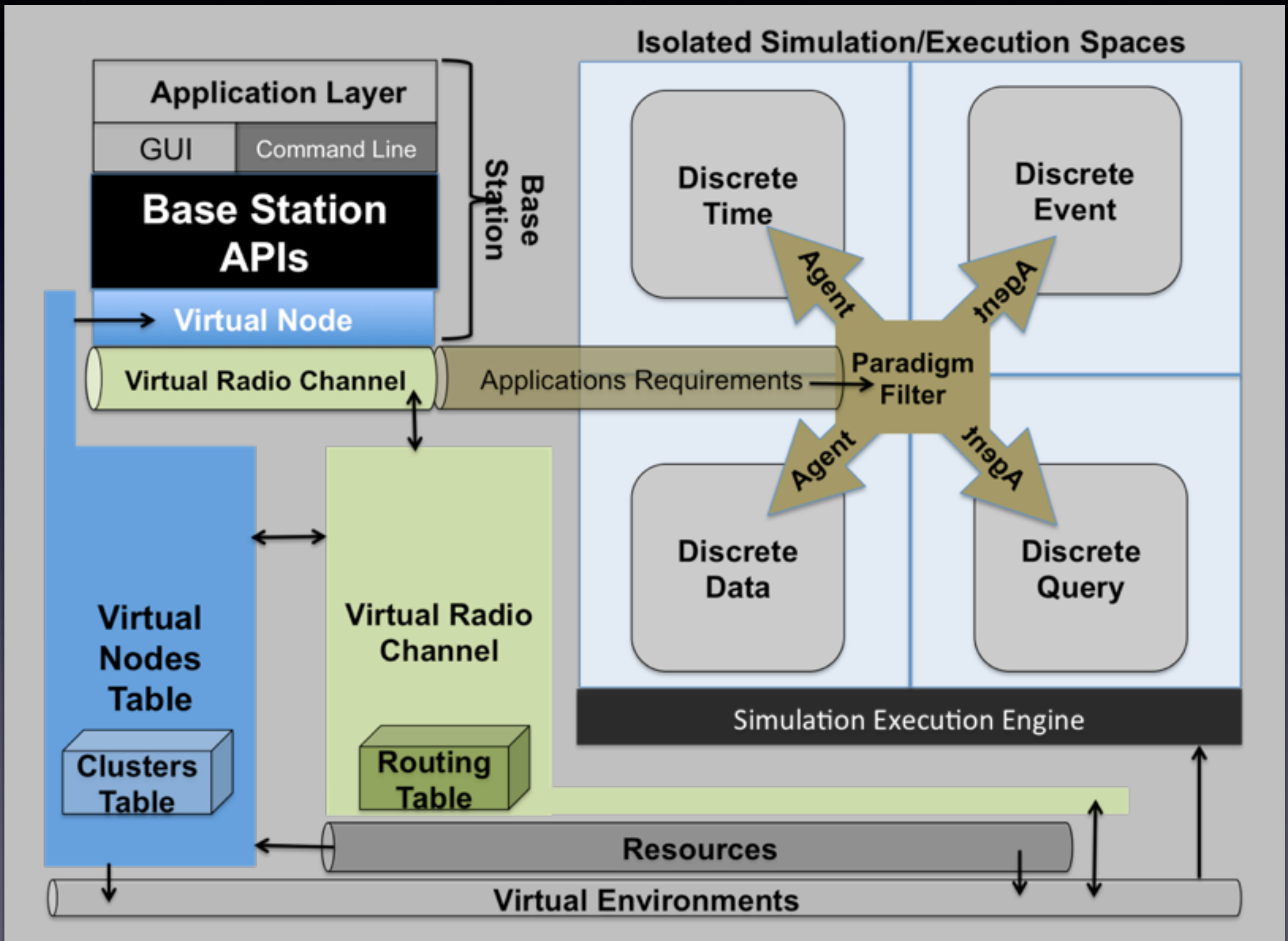


Virtual Data Generator
Data Injector
Real Data
Cluster A
Cluster B
Cluster C
Cluster D
Virtual Environment A
Virtual Environment B
Virtual Environment C
Virtual Environment D
Virtual Nodes Table
Aggregations
Resources
Computations
Instance of Environment
SXCS Dynamic Updater

Operational Paradigms

Query-driven
Data-driven
Time-driven
Event-driven

SXCS

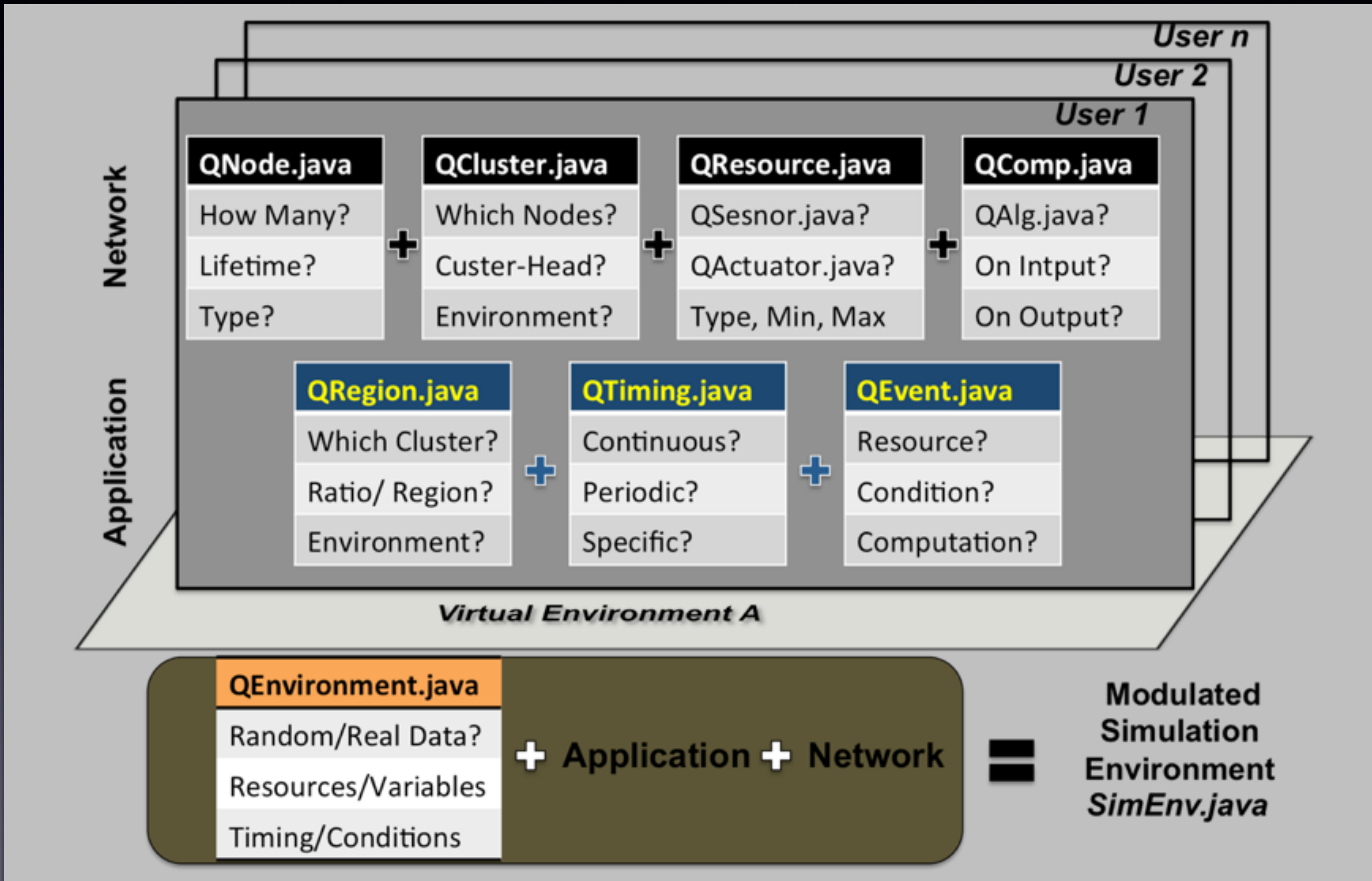

Isolated Simulation/Execution Spaces
Application Layer
GUI
Command Line
Base Station APIs
Base Station
Virtual Node
Virtual Radio Channel
Applications Requirements
Paradigm Filter
Discrete Time
Discrete Event
Discrete Data
Discrete Query
Agent
Agent
Agent
Agent
Virtual Nodes Table
Clusters Table
Virtual Radio Channel
Routing Table
Simulation Execution Engine
Resources
Virtual Environments

Paradigm-based Simulation

1) Allowing more realistic interactions between multi-operational applications
2) Allocating tailored execution model to optimize/analyze behavioral patterns
3) Enabling individual/collective virtual environments simulations
4) Faster interactions between environments and the applications
5) Concurrent evaluation of multiple nodes with different operational paradigms
6) Faster delivery of applications requirements to the nodes and environments
7) Observable impacts of paradigm-shifting on multiple levels

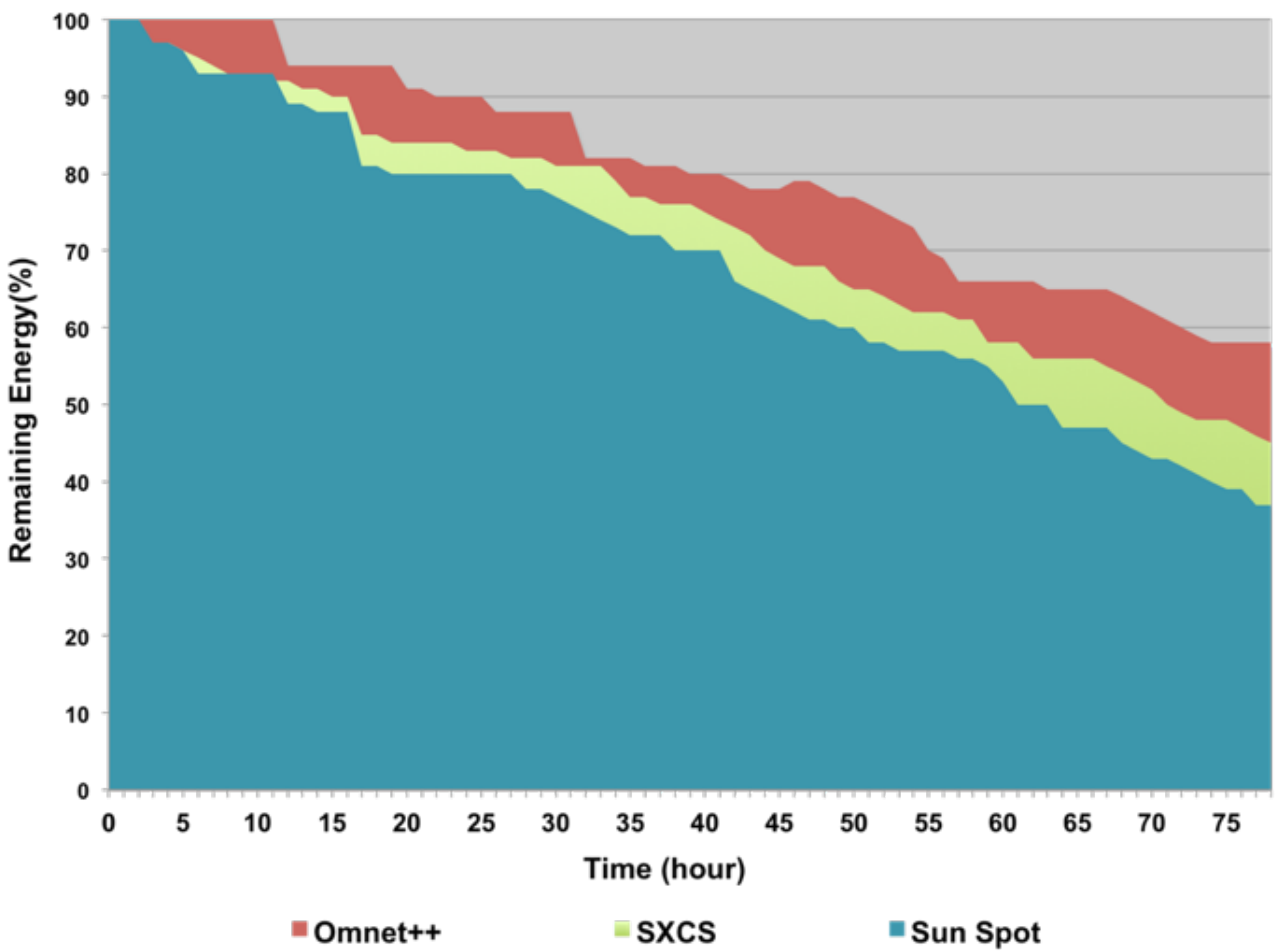
SXCS

Component Combination/Composition



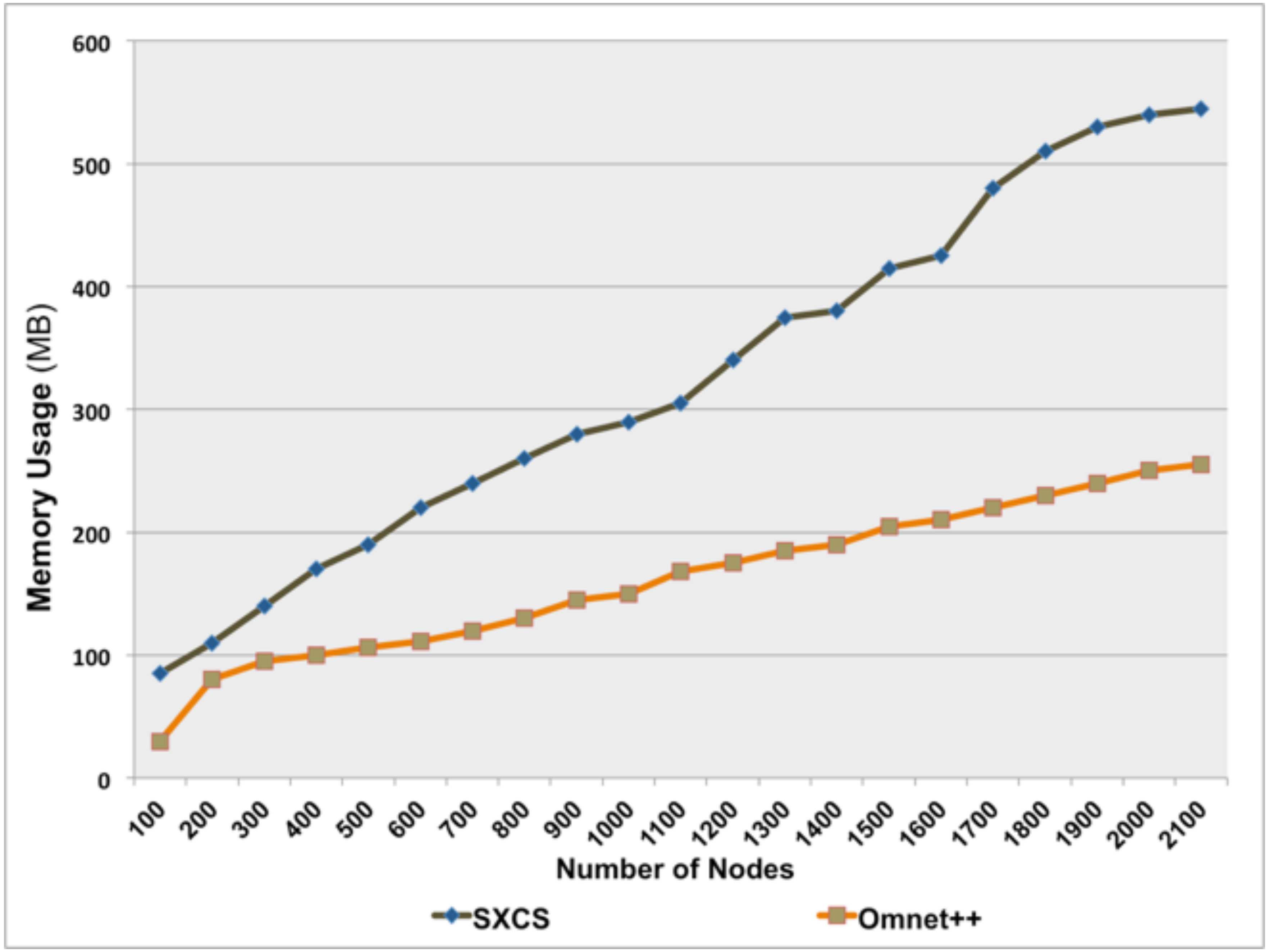
Benchmarking

Remaining Energy Estimation



Benchmarking

Memory Usage



Dynamic Data Storage Estimation for Multiple Concurrent Applications using Probability Distribution Modeling in WSNs

Thank You