Wireless Sensor Network Description Language (WSNDL) and Beyond

KanseiGenie Team:
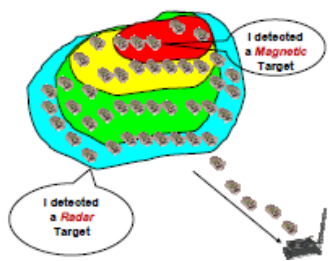
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THE OHIO STATE UNIVERSITY

Wayne State University

Los Alamos NATIONAL LABORATORY

Sun microsystems

WSN experimental infrastructures

A Line in the Sand

ExScal

VigilNet

moteLab

Kansei

NetEye WSU
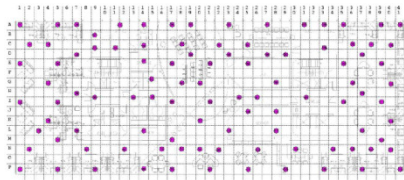
Mirage Intel
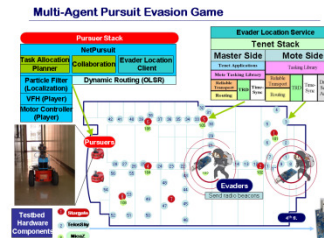
Tutornet USC

Mirage UMN

CitySense

No specification for
LINKs

Lack of experiment predictability/repeatability

- Conflicting experiment observations
  - Examples
    - wireless interference model (physical vs. protocol)
    - data collection protocol (for periodic monitoring vs. bursty events)
  - Major cause: many uncertainty factors are left unspecified, unmeasured, and implicit

- WSN resource specification is difficult
  - Complex dynamics and uncertainties in WSN
  - Heterogeneous platforms, protocols, and applications

Outline

- Principles and mechanisms of WSN RSpec

- Wireless Sensor Network Description Language (WSNDL)

- WSN federation architecture and RSpec implementation

- Open questions

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RSpecs for uncertainty factors

- Principle #1: Distinguish specified properties of interest as *controlled* or *observed*

  - Controllable factors: co-channel interference …

    Observable-only factors: slow time-varying wireless path loss …

  - Controllability is context-specific: control by "choice" in WSN federations

    – Path loss exponent …

- Mechanism: System choose/maintains controllable factors, and monitor/measures observable factors

  - RSpec embedding, passive/active monitoring techniques

  - Resource provisioning for monitoring

Network-centric WSN RSpec

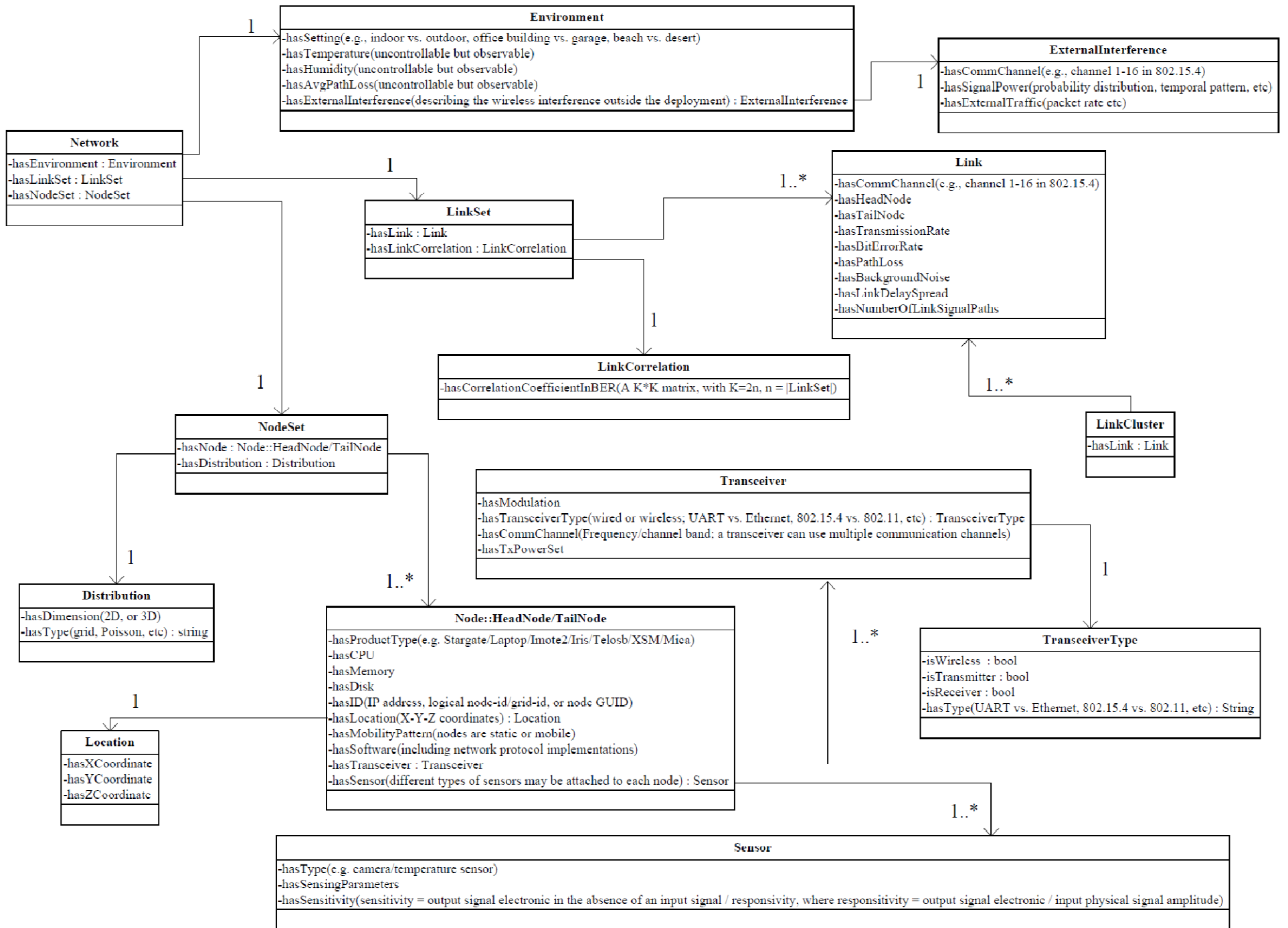- Principle #2: Enable reasoning about *relationship/ dependencies* among resources
  - Geometric relation among nodes, channel relation (e.g., path loss) among nodes, correlation among links
  - Dependencies among node, radio, and spectrum

- Mechanism: Network-centric measurement and embedding
  - Passive/active monitoring techniques for characterizing relationships/dependencies
  - RSpec embedding

RSpec for heterogeneous, federated WSNs

- Principle #3: Embrace *heterogeneity/diversity* in RSpec
  - Heterogeneity in resource and resource ontology
    - No consensus on basic issues such as WSN addressing (IP or not)
  - Heterogeneity in RSpec use cases
    - Multiple levels of abstraction: low-level specs for system interactions, high-level specs for researchers and opt-in users

- Mechanism: Enable ontology mapping
  - From high-level spec to low-level spec
  - Between heterogeneous low-level specs

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Environment

-hasSetting(e.g., indoor vs. outdoor, office building vs. garage, beach vs. desert)
-hasTemperature(uncontrollable but observable)
-hasHumidity(uncontrollable but observable)
-hasAvgPathLoss(uncontrollable but observable)
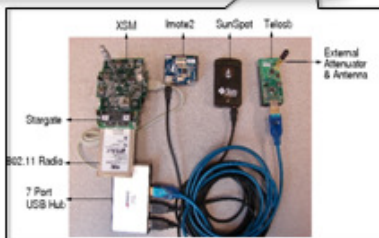-hasExternalInterference(describing the wireless interference outside the deployment) : ExternalInterference

ExternalInterference

-hasCommChannel(e.g., channel 1-16 in 802.15.4)
-hasSignalPower(probability distribution, temporal pattern, etc)
-hasExternalTraffic(packet rate etc)

Network

-hasEnvironment : Environment
-hasLinkSet : LinkSet
-hasNodeSet : NodeSet

Link

-hasCommChannel(e.g., channel 1-16 in 802.15.4)
-hasHeadNode
-hasTailNode
-hasTransmissionRate
-hasBitErrorRate
-hasPathLoss
-hasBackgroundNoise
-hasLinkDelaySpread
-hasNumberOfLinkSignalPaths

LinkSet

-hasLink : Link
-hasLinkCorrelation : LinkCorrelation

LinkCorrelation

-hasCorrelationCoefficientInBER(A K*K matrix, with K=2n, n = |LinkSet|)

LinkCluster

-hasLink : Link

NodeSet

-hasNode : Node::HeadNode/TailNode
-hasDistribution : Distribution

Transceiver

-hasModulation
-hasTransceiverType(wired or wireless; UART vs. Ethernet, 802.15.4 vs. 802.11, etc) : TransceiverType
-hasCommChannel(Frequency/channel band; a transceiver can use multiple communication channels)
-hasTxPowerSet

Distribution

-hasDimension(2D, or 3D)
-hasType(grid, Poisson, etc) : string

Node::HeadNode/TailNode

-hasProductType(e.g. Stargate/Laptop/Imote2/Iris/Telosb/XSM/Mica)
-hasCPU
-hasMemory
-hasDisk
-hasID(IP address, logical node-id/grid-id, or node GUID)
-hasLocation(X-Y-Z coordinates) : Location
-hasMobilityPattern(nodes are static or mobile)
-hasSoftware(including network protocol implementations)
-hasTransceiver : Transceiver
-hasSensor(different types of sensors may be attached to each node) : Sensor

TransceiverType

-isWireless : bool
-isTransmitter : bool
-isReceiver : bool
-hasType(UART vs. Ethernet, 802.15.4 vs. 802.11, etc) : String

Location

-hasXCoordinate
-hasYCoordinate
-hasZCoordinate

Sensor

-hasType(e.g. camera/temperature sensor)
-hasSensingParameters
-hasSensitivity(sensitivity = output signal electronic in the absence of an input signal / responsivity, where responsivity = output signal electronic / input physical signal amplitude)

Network
NodeSet
hasLinkSet
hasEnvironment

NodeSet
Node
Distribution

Node
Location
MobilityPattern
Transceiver
Sensor
...

Location
...

Transceiver
Modulation
CommChannel
TxPowerSet
...

Distribution
Dimension
...

Sensor
Type
SensingParameters
Sensitivity
...

LinkSet
Link
LinkCorrelation

Link
CommChannel
PathLoss
BackgroundNoise
...

LinkCorrelation
CorrelationCoefficientInBER
...

Environment
Setting
AvgPathLoss
ExternalInterference
... ...

ExternalInterference
CommChannel
SignalPower
...

→ : hasProperty
1 : one to one mapping
1..* : one to one/many mapping

underline: measurable (only)

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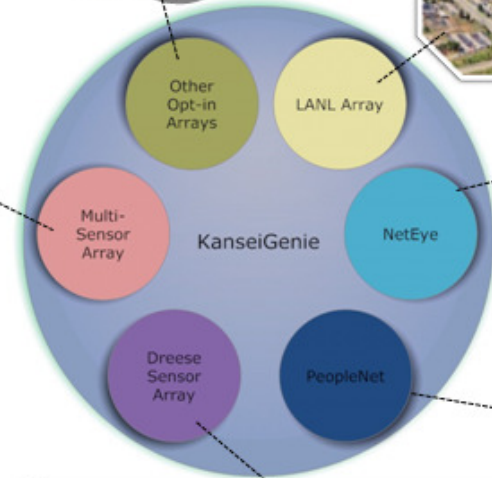
- Open questions

WSN federation architecture

Federated resource manager (FR): resource discovery and allocation
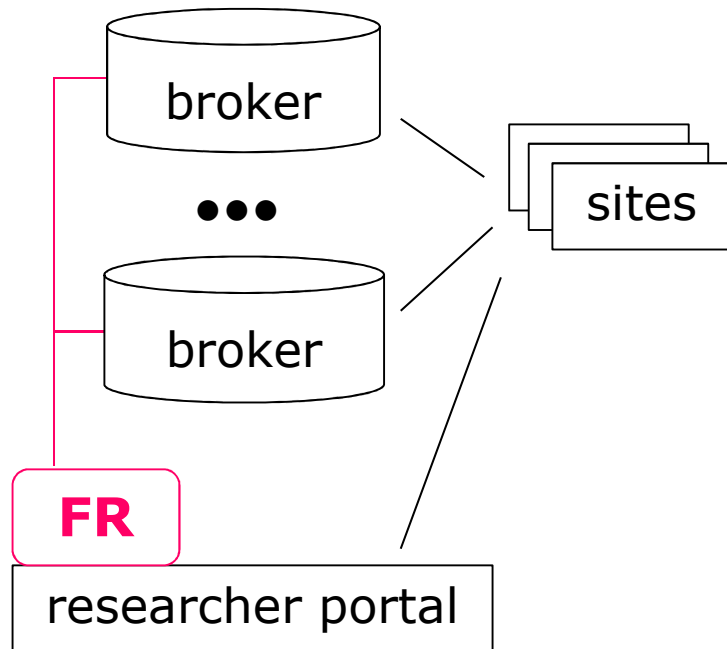
Option 1
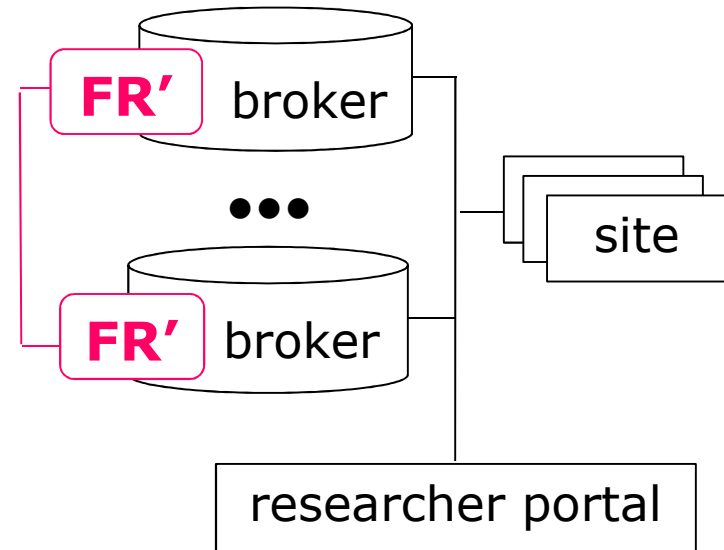
Option 2

RSpec implementation
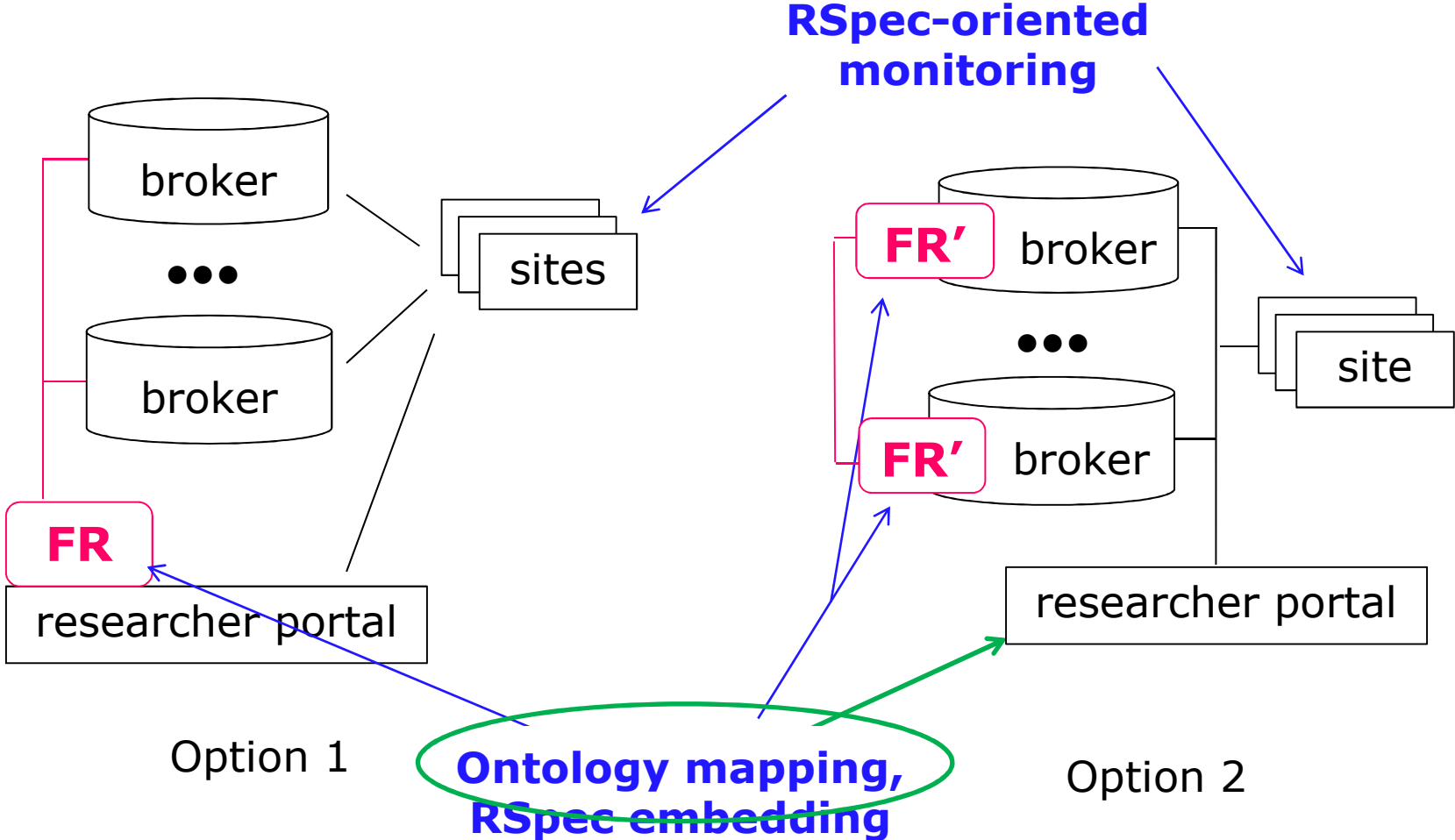
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- Wireless Sensor Network Description Language (WSNDL)

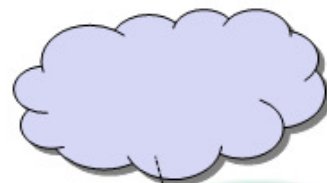- WSN federation architecture and RSpec implementation

- Open questions

Open questions

- Measurement
  - Granularity vs. overhead/cost
  - Experiment itself vs. system service
  - Dynamics vs. fidelity
- Embedding
  - Ontology mapping
  - Spatial constraint
- High-level RSpec
  - Heterogeneous use cases and abstractions
- Integration
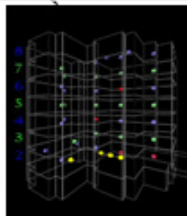 - Sensor network , mesh network, vehicular network, cellular network

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- **At-scale testing**
- **Multi-array applications**
- **Hybrid experimentation**
- Services-model of interaction
- Sensor data injection
- Object code, source code or high-level language input

- Sensor and mesh networking expt.
- Interactive experimentation control, sensing and control data injection
- Privacy-preserving user view control
- **Urban, health/occupational sensing**

15 802.11b/g laptops

130 TelosB motes

Other Opt-in Arrays

LANL Array

Multi-Sensor Array

KanseiGenie

NetEye

Dreese Sensor Array

PeopleNet

- **P2P social networking apps**
- **Environmental sensing: NOX,CO_2**
- **Mobility testing**

Cell-phone Psi-Mote Mobile Array

Dreese Sensors
- ● Occupancy
- ● Elevator
- ● Temperature
- ○ Anchor Nodes

- Location-specific user-supplied sensing (conference room occupancy, elevator location)
- Fabric virtualization

User Application ---
KanseiGenie Services ---
Client Services ---
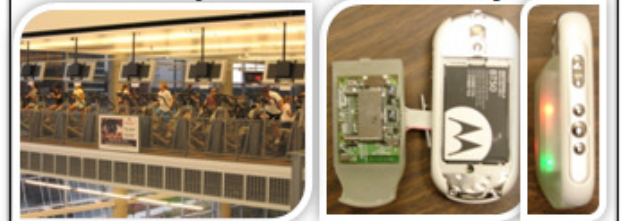
Backup slides

WSN extension to NDL: examples

- Radio
  - High-level: standard-based spec such as Zigbee and WiMedia
  - Low-level: wireless spectrum, modulation , (programmable) network stack

- Neighborhood
  - High-level: connectivity (e.g., neighborhood size)
  - Low-level: node location, link properties, *correlation among links* …

- Environment
  - High-level: application context (e.g., home vs. industrial)
  - Low-level: path loss, *interference from co-existing nets* …