Integrating the Physical World over the Cyber World: Federated Sensor Networks Prospects and Challenges

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Chamonix / Mt Blanc - France

Integrating the Physical World through the Cyber World:

Federated Sensor Networks Prospects and Challenges

- **Abstract**: Wireless Sensor Network is considered as one of the important and fast growing technologies that are penetrating through almost every aspect of life. The prospect, with the modern hat of Internet of Things/nano-Things, reflects future potential and complements that of the Internet. Research and development of concepts related to sensor networks are driving towards taking the experiments from the laboratory into the field with emphasis on various modes of communications including Machine-to-Machine communications. A wide range of testbeds has been established for remotely testing design ideas on various physical environments. These testbeds have created real test environments and stimulated research into related architectures and solutions. Virtual support for extending the capabilities of such environments has also been explored. This aims at enabling the mix and match among available resources of multiple testbeds in formulating workable federation. Areas like data and reality mining, Internet of Things and Nano-Things, spatial-cyber systems and others have started pushing towards the formulation of highly complex systems. These systems are centred round the Internet and sensor networks and are driving towards what has been referred to as the planet nervous system. While elements of the concept have started taking shape, there are significant operational and optimization challenges. The synergy among the various acting subsystems, the redundancies of multiple solutions on the same physical space, and the physical and radio pollution impacting the living spaces are just to name few. The talk will provide highlights to wireless sensor network technologies. It will introduce examples taken from the experience of AUT SeNSe research laboratory. Further the talk will shed the light on the area of WSN federated testbeds and related challenges.

- **Biography**: Adnan Al-Anbuky http://sense.aut.ac.nz/adnan.cfm received his Ph.D. degree from UMIST, Manchester, U.K., in 1975. During 1975 to 1995 he has assumed a number of academic positions including being dean of the faculty of engineering within Yarmouk University of Jordan. Professor Al-Anbuky joined Switchec/ NZ on 1996 and started establishing an industrial research unit driving toward increasing the level of automation within the telecommunication power systems service industry. This has led to numerous patents and publications on top of various concepts for products. Late 2005 he joined AUT as a professor and head of electrical and electronics engineering department. The establishment of the Sensor Network and Smart Environment (SeNSe) research centre http://sense.aut.ac.nz/ in mid-2006 has led to a number of projects that benefited both the local and international communities. Adnan is a member of advisory group of AUT technology park and member of the editorial board of the Journal Sensors and actuator networks. He has more than 10 granted patents and numerous publications. He has also chaired good number of specialized conferences and workshops.


Whangarei
Auckland
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New Plymouth
Rotorua
Gisborne
Palmerston North
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Wellington
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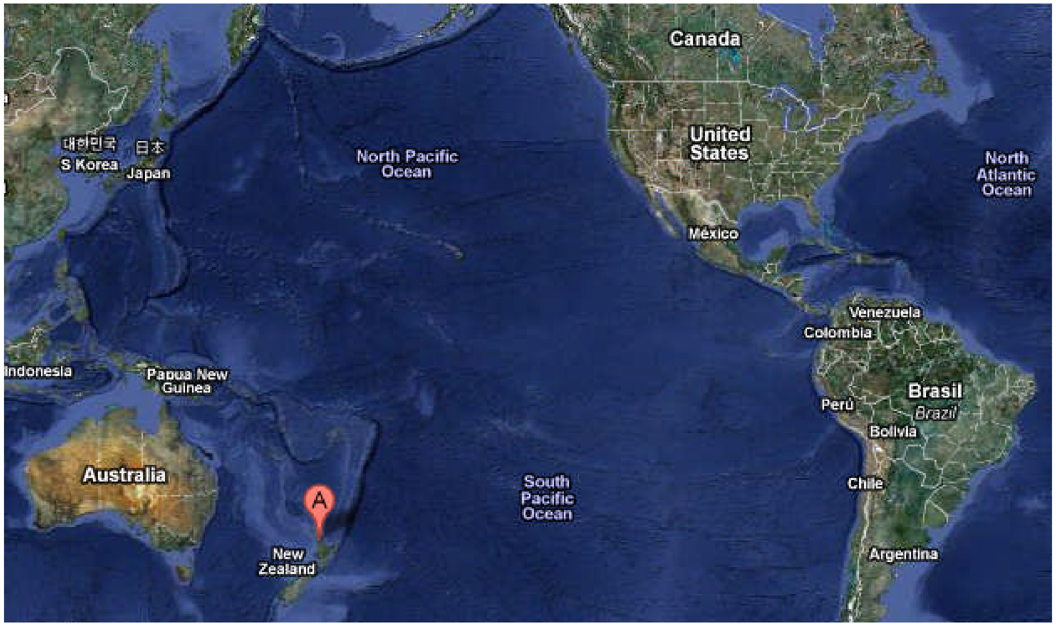
Blenheim
New Zealand
Christchurch
Timaru
Waimate
Oamaru
Dunedin
Gore
Invercargill


Canada
대한민국
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United States
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Colombia
Indonesia
Papua New Guinea
Brasil
Brazil
Perú
Bolivia
Australia
A
South Pacific Ocean
Chile
New Zealand
Argentina


Auckland-Half Moon Bay Ferry
Auckland Beachlands Ferry
Freemans Bay
Viaduct Basin
Quay St
Auckland Britomart
Victoria Park
Auckland
Sky Tower
Albert Park
Carlaw Park
Myers Park
Parnell


http://www.youtube.com/watch?v=GbxYZ97yNkI&feature=fvwrel
http://www.youtube.com/watch?v=mb7aVOCEBw0

Talk Overview

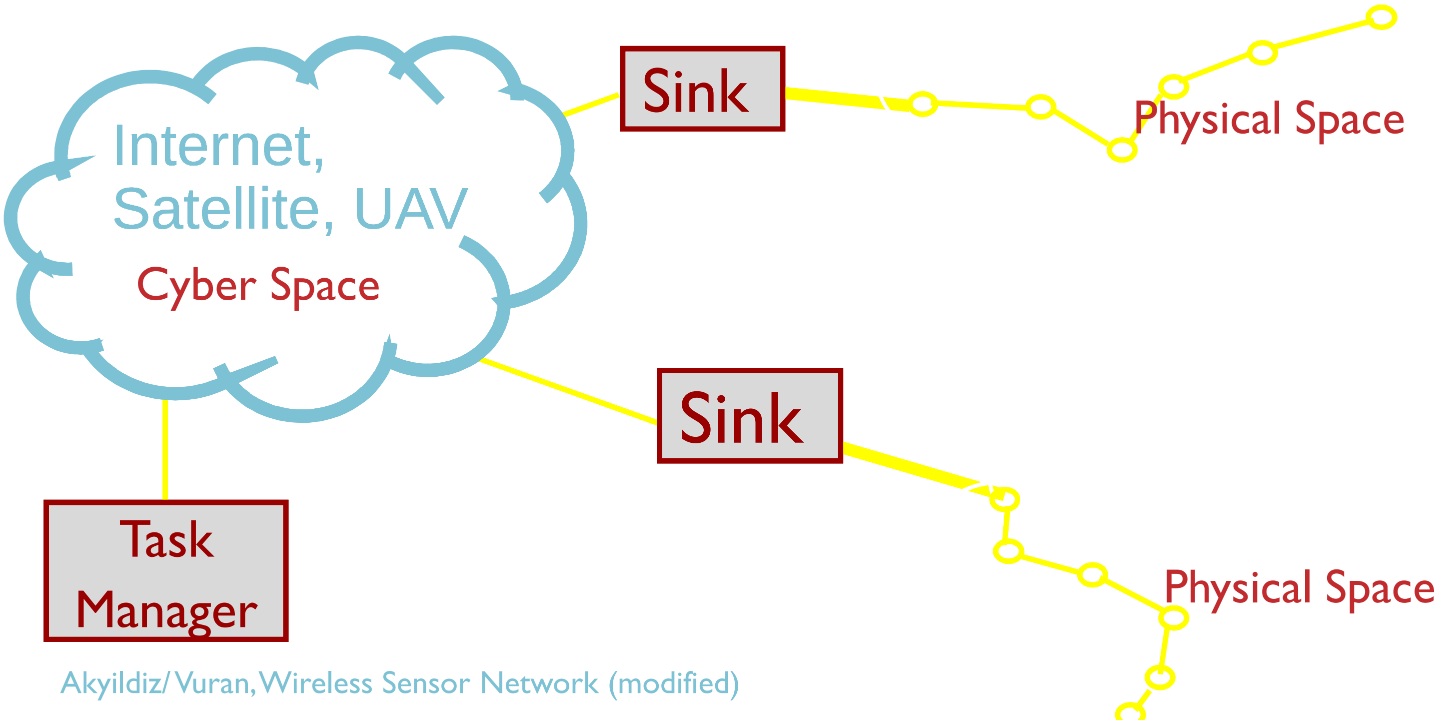
- **Sensor Network Background**
- Example Applications
  - Smart Farming
  - Spatial Mapping
- Sensor Network Testbeds
- Vision for the Federation
- Other Related Technologies
- Other Remarks & Conclusions

General features of WSN

- Monitoring the physical phenomena: Largely deployed either inside or closed-by
- Coverage of large space: through tiny sensors that have the capability of sensing, processing and communication
- Low cost, Low power, & multifunctional Sensor nodes
- Feasibility of nodes that are small in size and able to communicate within short distances
- Advances in MEMS, Wireless communication, and digital technologies
- Spatio-temporal correlation: Dense deployment coupled with physical properties of sensed phenomenon
- Self-organized communication protocol: Encourage random deployment, multi-hop communication help dense network.
- Data fusion: help reducing the size of insignificant or raw data that are communicated

General Topology

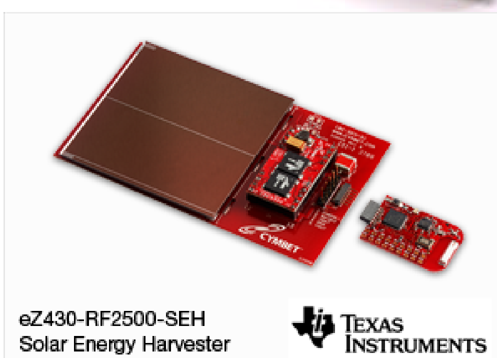
Group of sensors covering a given physical space to provide sensed data on the phenomenon that need to be monitored.

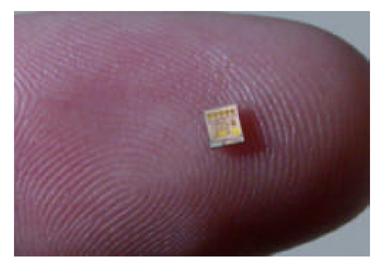


Akyildiz/ Vuran, Wireless Sensor Network (modified)

Sensors Technologies

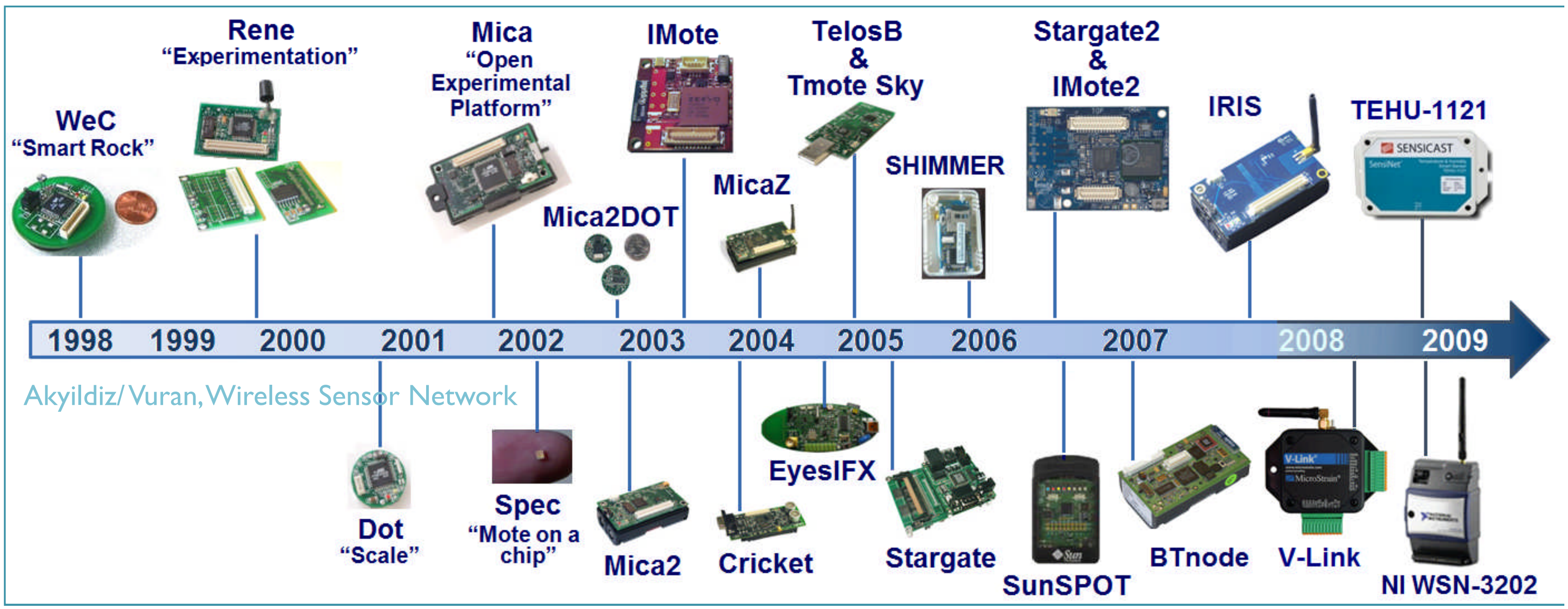
- Sensing, Computation resources, Communication Protocol, Radio, Energy Source (harvesting)
- Size (miniaturization) & Cost
- Operating Software/ middleware
- Others





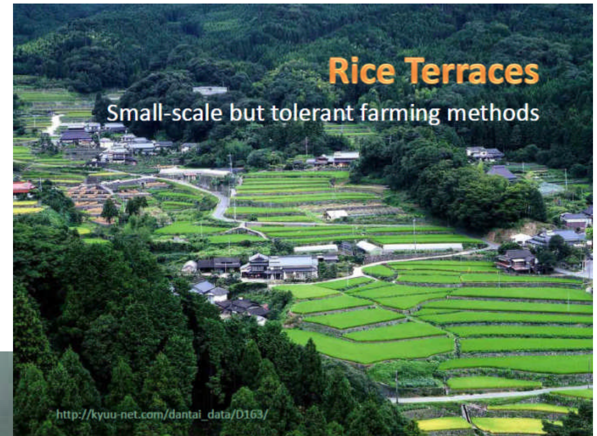
Sensor Motes Timeline

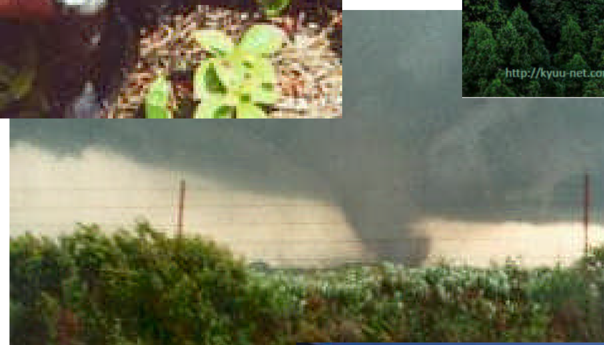
- **General features:** Processing Speed, Memory Size, Operating frequency, and transmission rate, IEEE 802.15.4 Protocol, CC2450 transceiver
- **Low end Platform:** Sensing and connectivity infrastructure
- **High-End Platform:** more involved functionalities (e.g. DSP), local processing and multi-hop communication



Akyildiz/Vuran, Wireless Sensor Network

Sample Applications



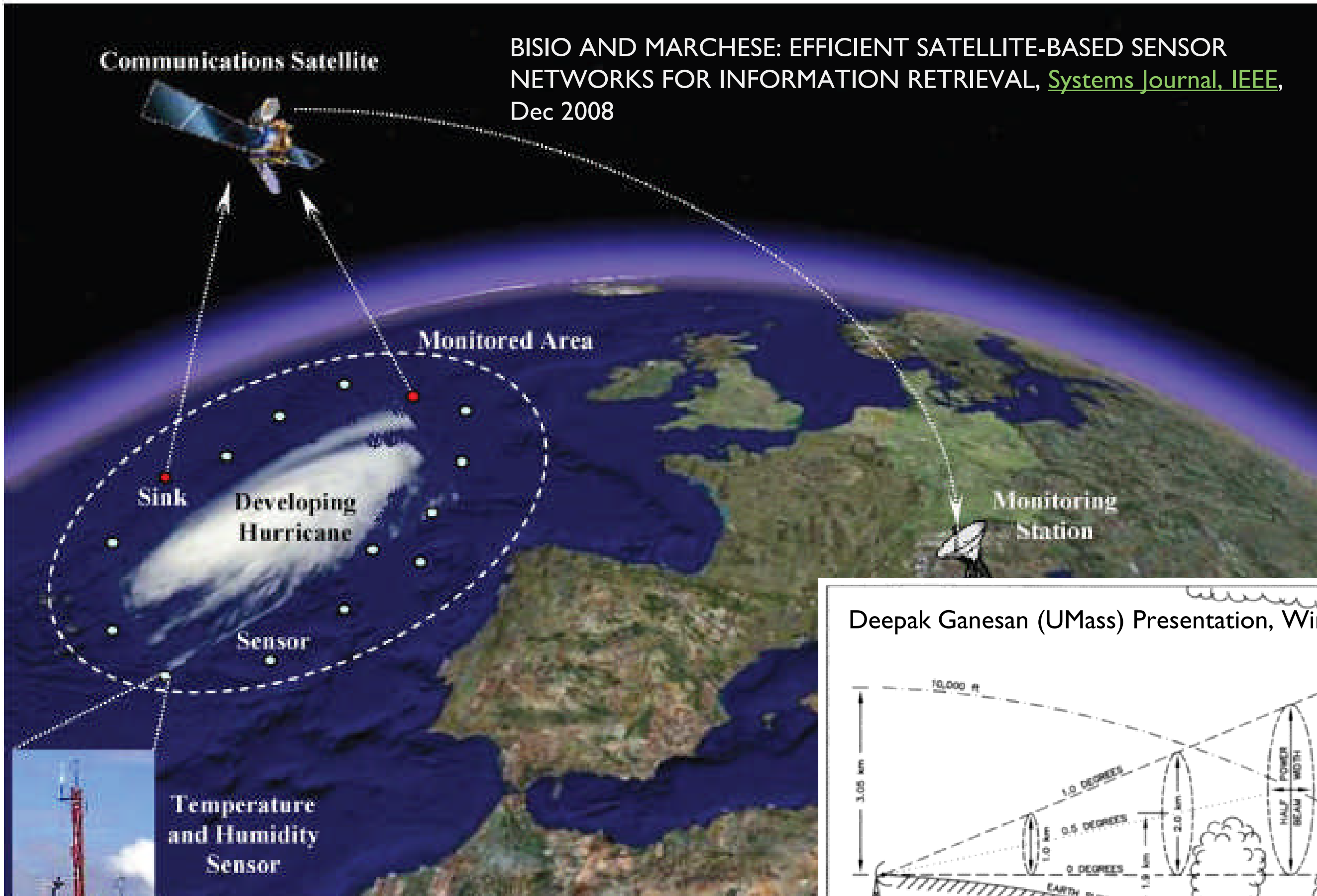


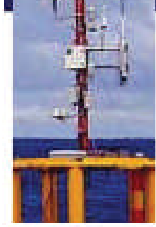
Common Challenging Issues

- Limited computation and data storage
- Low power consumption
- Wireless communication
  - Medium, ad hoc vs. infrastructure, topology and routing
- Data-related issues
- Continuous operation
- Inaccessibility – network adjustment and re-tasking
- Robustness and fault tolerance

Trading the Macro Sensing with the Micro/nano Sensing

BISIO AND MARCHESE: EFFICIENT SATELLITE-BASED SENSOR NETWORKS FOR INFORMATION RETRIEVAL, Systems Journal, IEEE, Dec 2008





Example of EMS for weather prediction.

Deepak Ganesan (UMass) Presentation, Wireless Sensor Networks

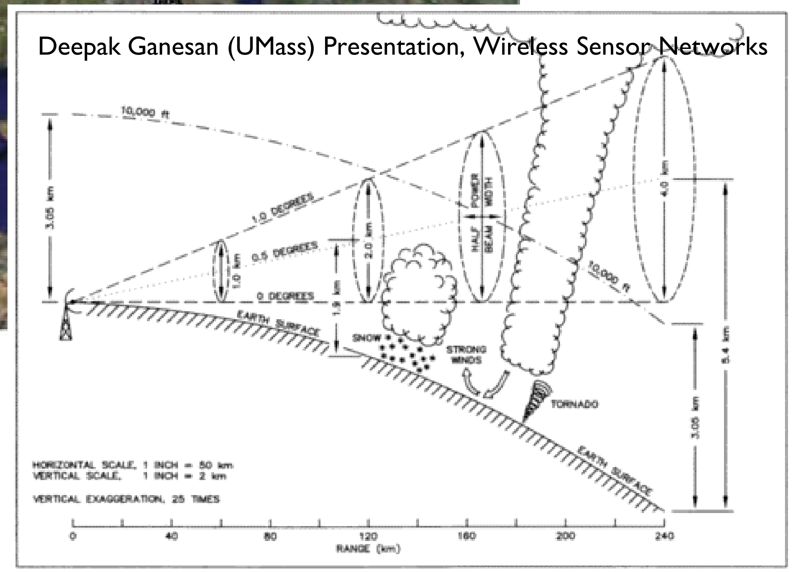
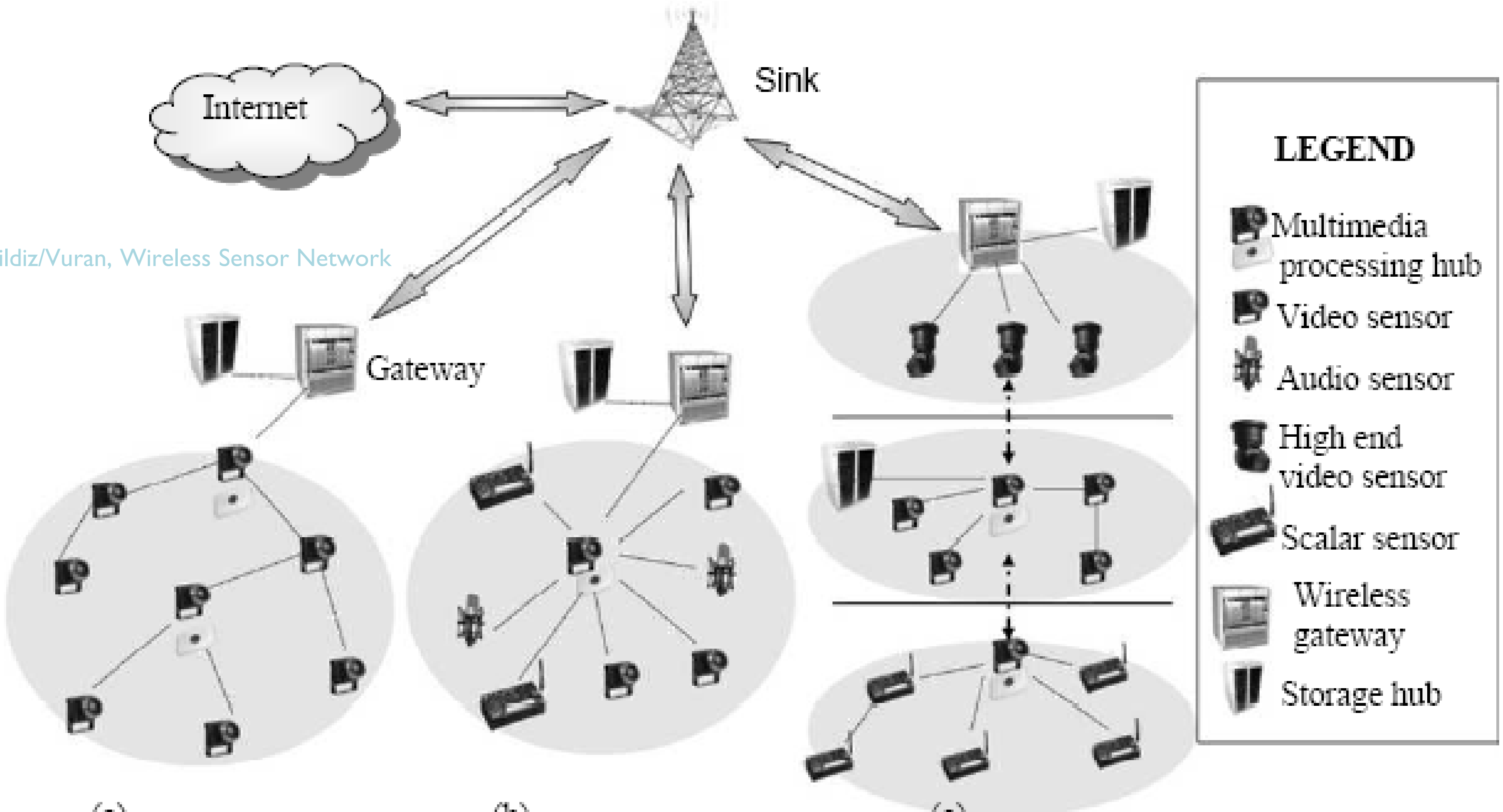


Figure A-3 Diagram illustrating the effect of range and earth curvature (with standard atmospheric refraction) on NEXRAD cross-beam resolution and coverage of low-level weather phenomena. Courtesy of SRI International.

Sensor Network Topology

Akyildiz/Vuran, Wireless Sensor Network



(a) Single-tier flat, homogeneous sensors, distributed processing, centralized storage

(b) Single-tier clustered, heterogeneous sensors, centralized processing, centralized storage

(c) Multi-tier, heterogeneous sensors, distributed processing, distributed storage

Components of Infrastructure

Ramesh Govindan, USC, Embedded Networks Lab , WSN Tutorial

Collaborative Event Processing

Querying, Triggering

Data-centric Routing | Aggregation and Compression | Data-centric Storage

Collaborative Signal Processing

Localization | Time Synchronization | Medium Access | Calibration

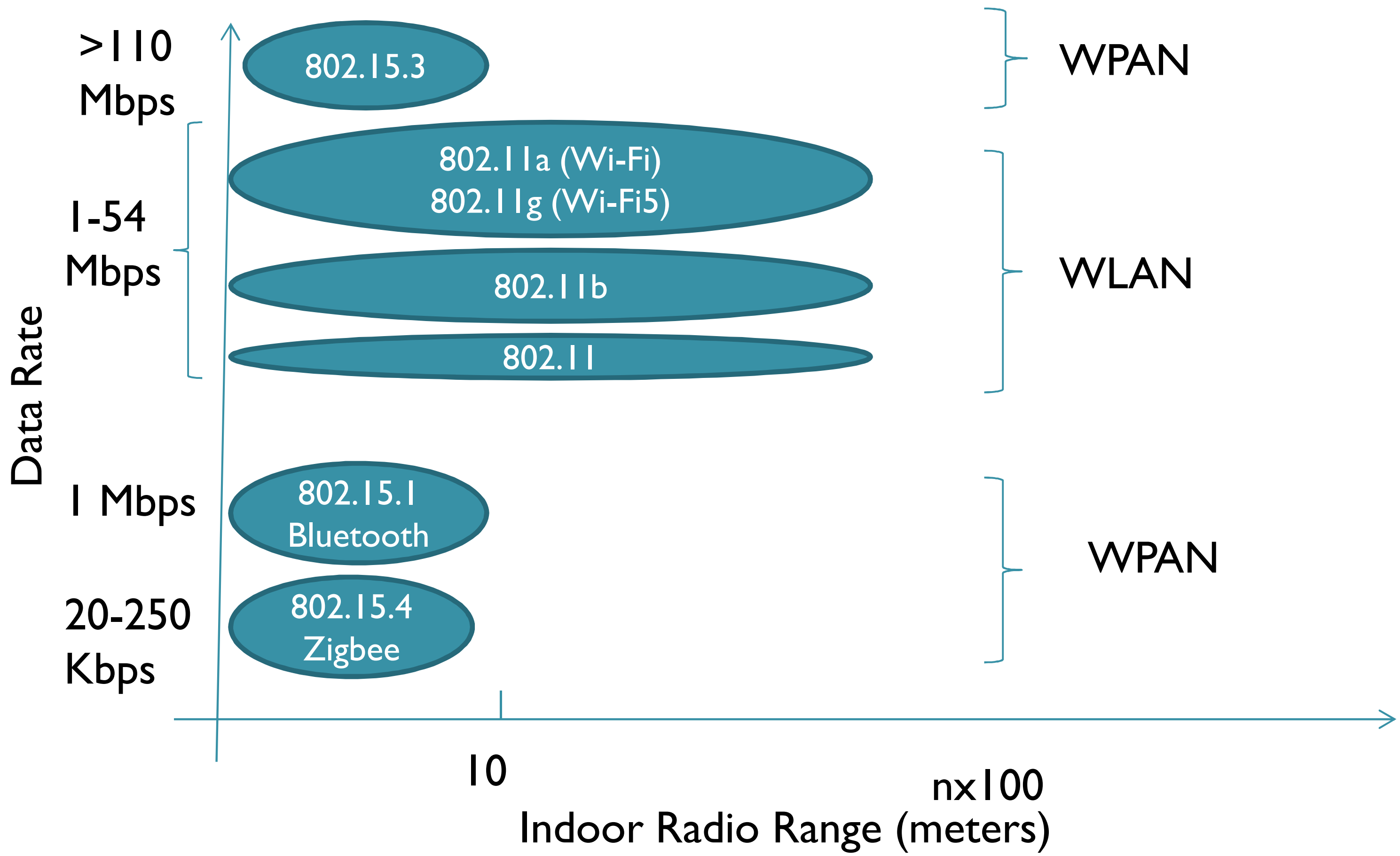
Operating Systems

Processor Platforms | Radios | Sensors

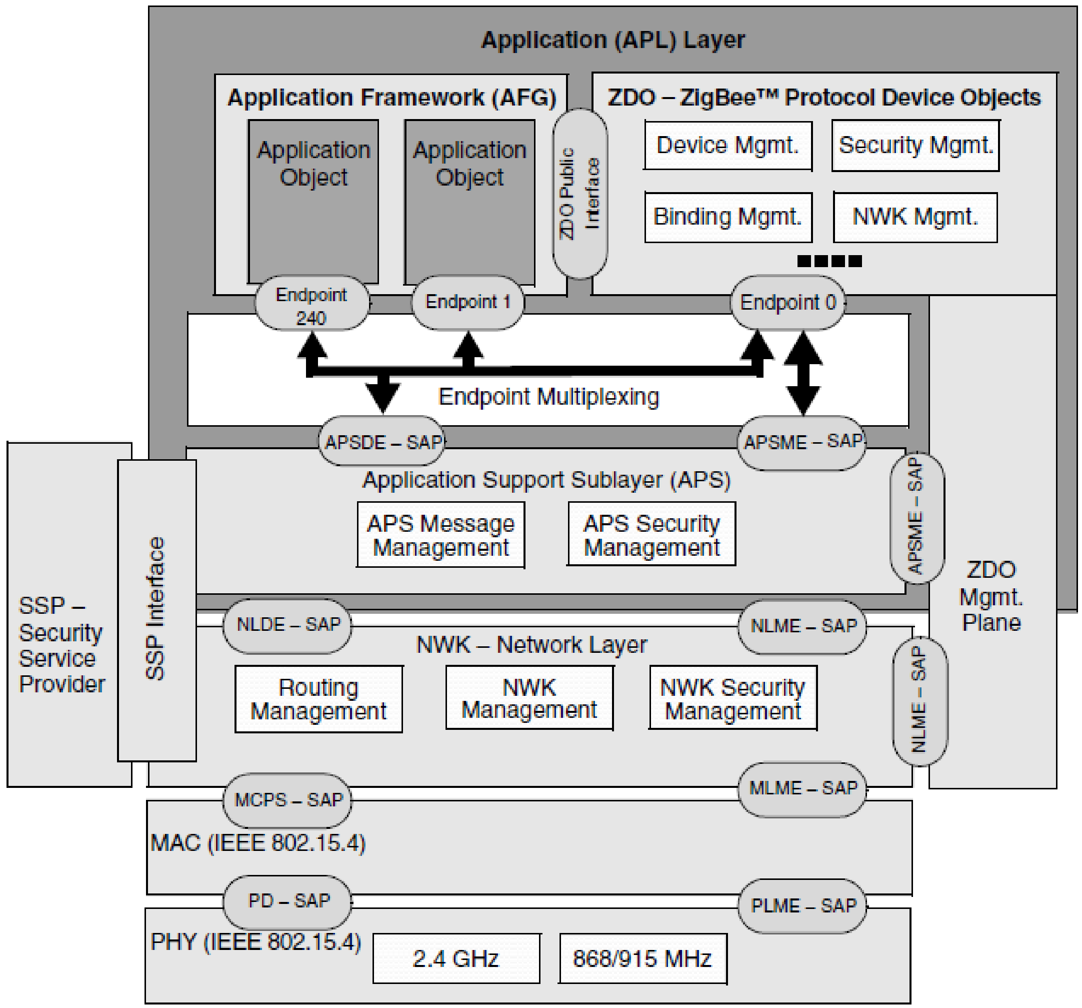
Monitoring

Security

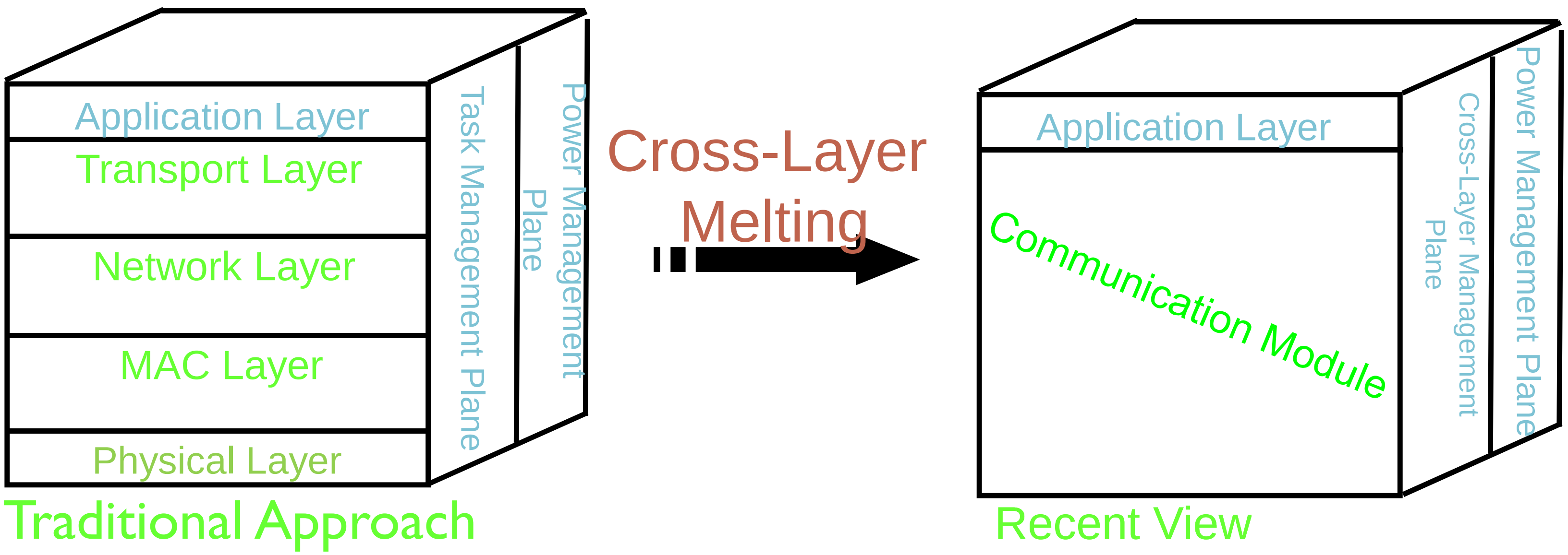
Wireless local networks protocols



Zigbee™ Protocol Stack Architecture



Possible Vision Towards WSN Communication Protocol



Akyildiz/Vuran, Wireless Sensor Network

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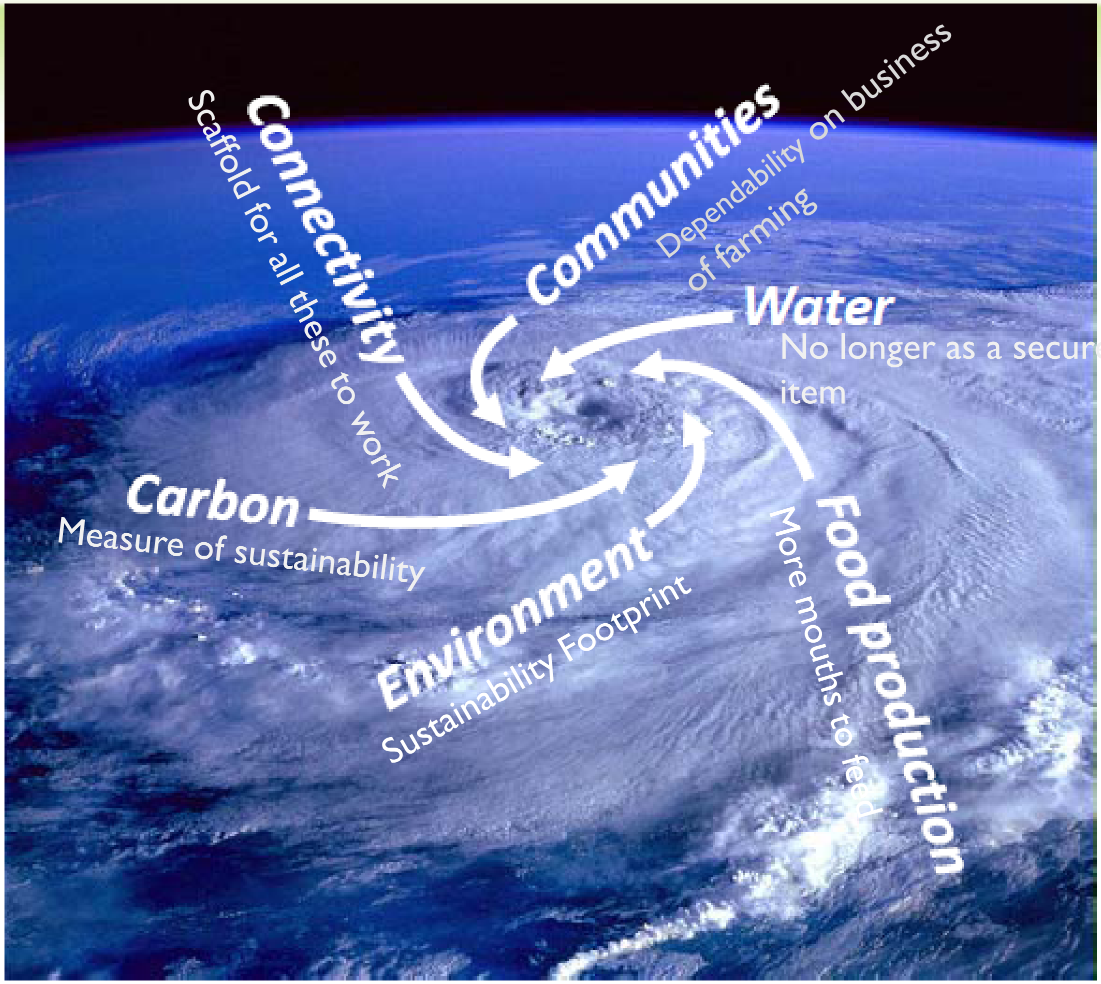
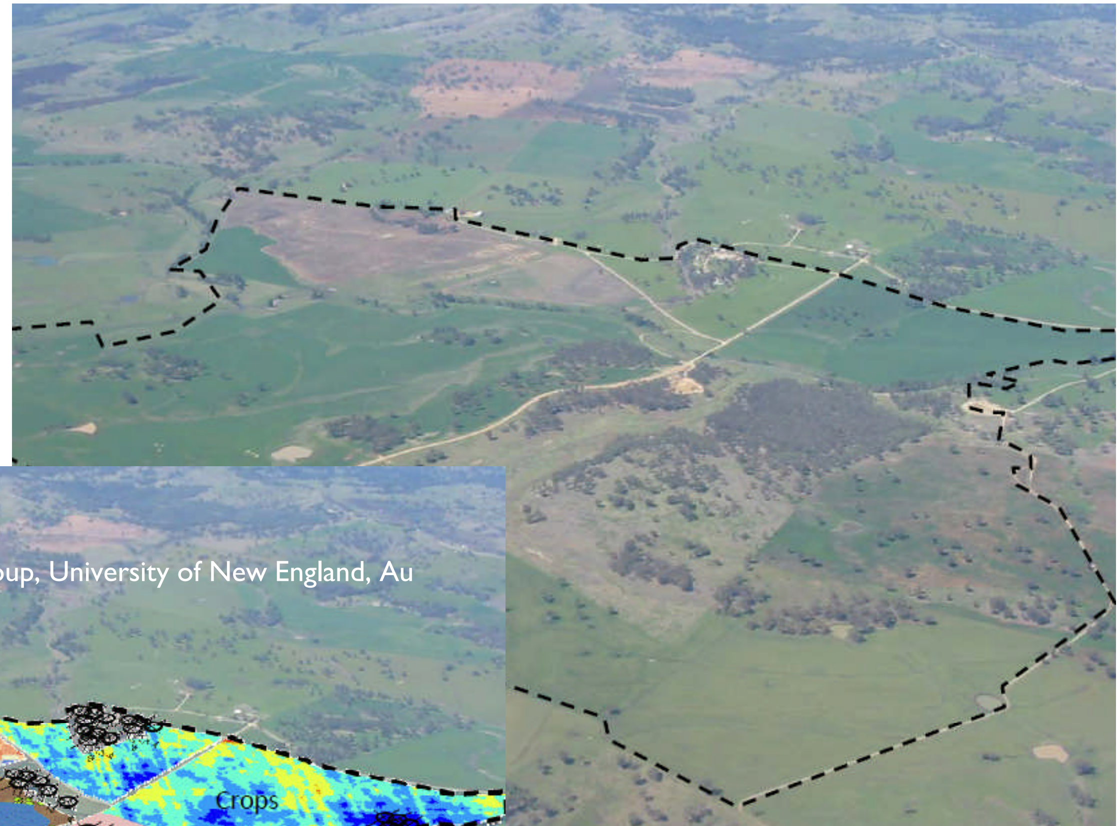
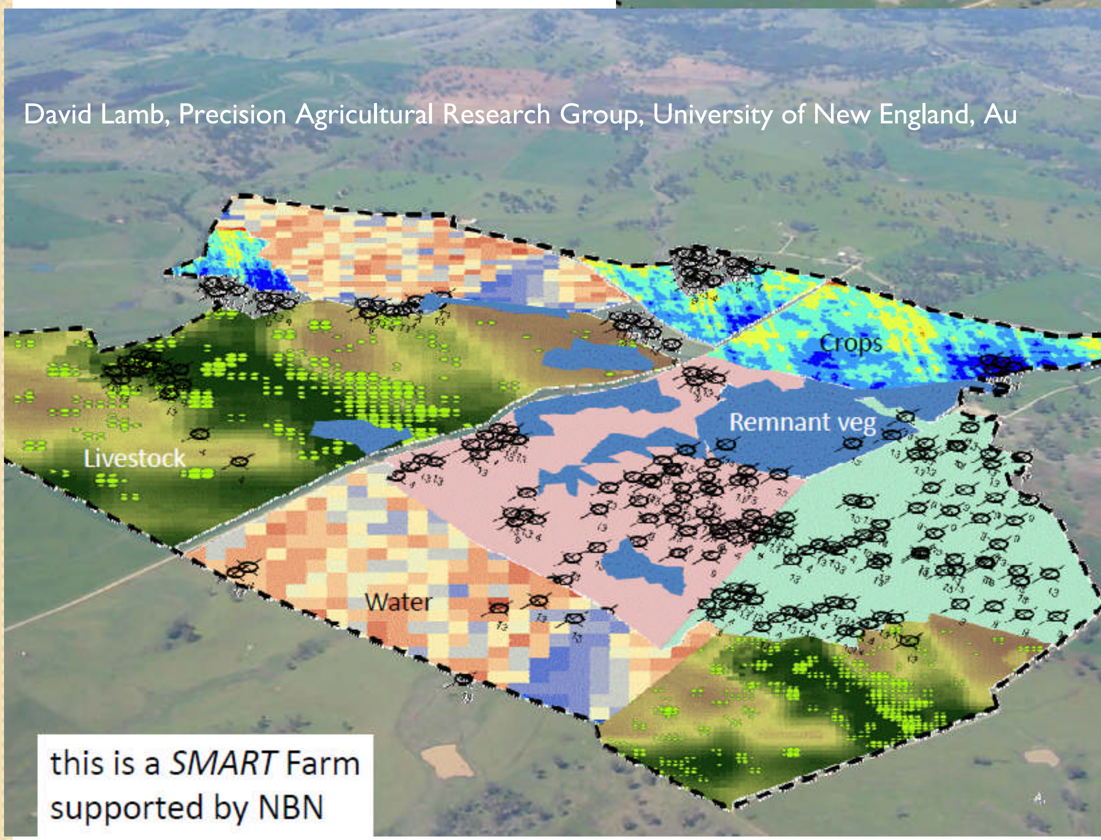
The ***perfect storm*** of farming

David Lamb, Precision Agricultural Research Group, University of New England, AU



Smart Farming

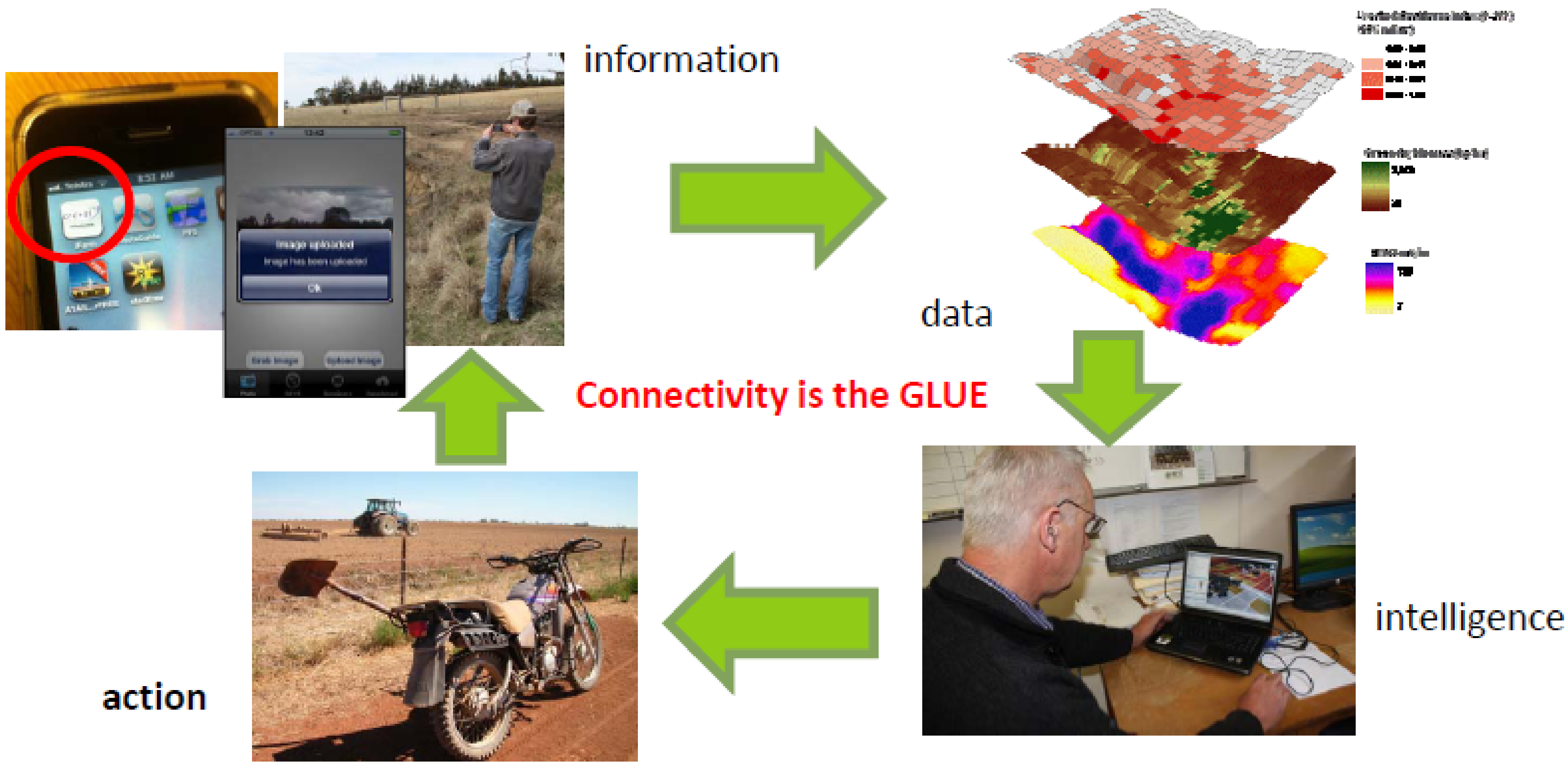




The *SMART* farm

David Lamb, Precision Agricultural Research Group, University of New England, AU

- A *Command Centre* remotely supported by regional businesses



Showcasing the benefits of regional connectivity

David Lamb, Precision Agricultural Research Group, University of New England, AU

Productivity

Sustainability

Accessibility

- Pathways to improved production (Precision Agriculture)
  - ~10-30% reduction in fertiliser input (rainfed and irrigated crops)
  - ~50-100% improvement in yield:water ratio (irrigated crops)
  - ~20% improvement in pasture use efficiency
- Pathways to improved efficiencies,
  - Workflow improvements/labour reduction
  - Safety, health and well being
  - Integrated and improved health care (medical, disability)
  - Accurate record keeping
  - Trouble-shooting and problem solving
  - Business and management assistance
- Pathways to improving social inclusion and education
  - Community support services
  - Education and training
- Value-adding enterprise clusters
  - Centralised and decentralised business opportunities for regional communities (farm, advisory & technology services)
  - Community regeneration
  - Retention of local skills

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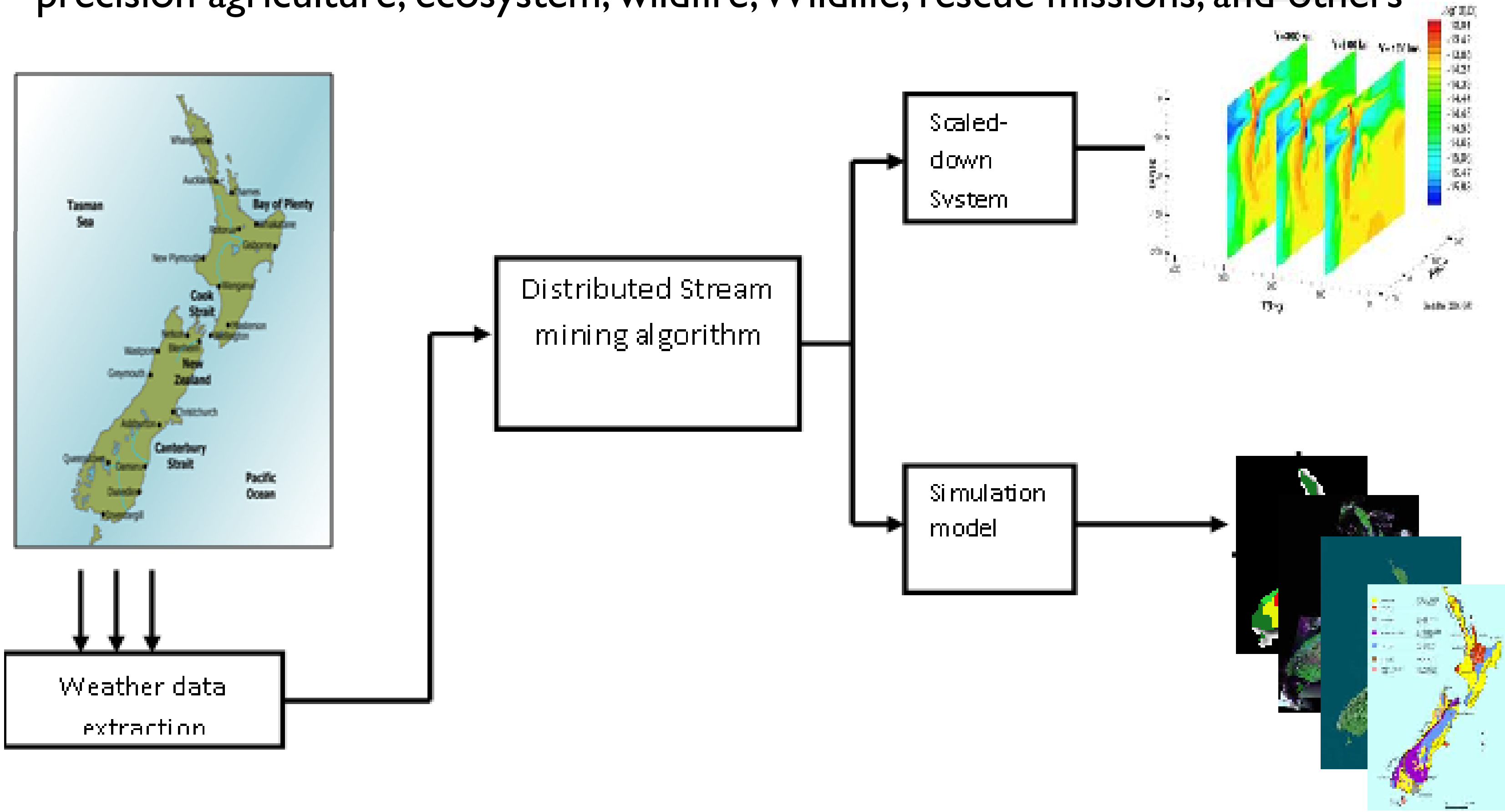
Outdoor Spatial Mapping

KAHURANGI NATIONAL PARK

• Try to facilitate coverage to important spots relevant to the ecosystem, wildlife or human rescue/support
• Complement the existing infrastructure for better spatial and temporal resolution

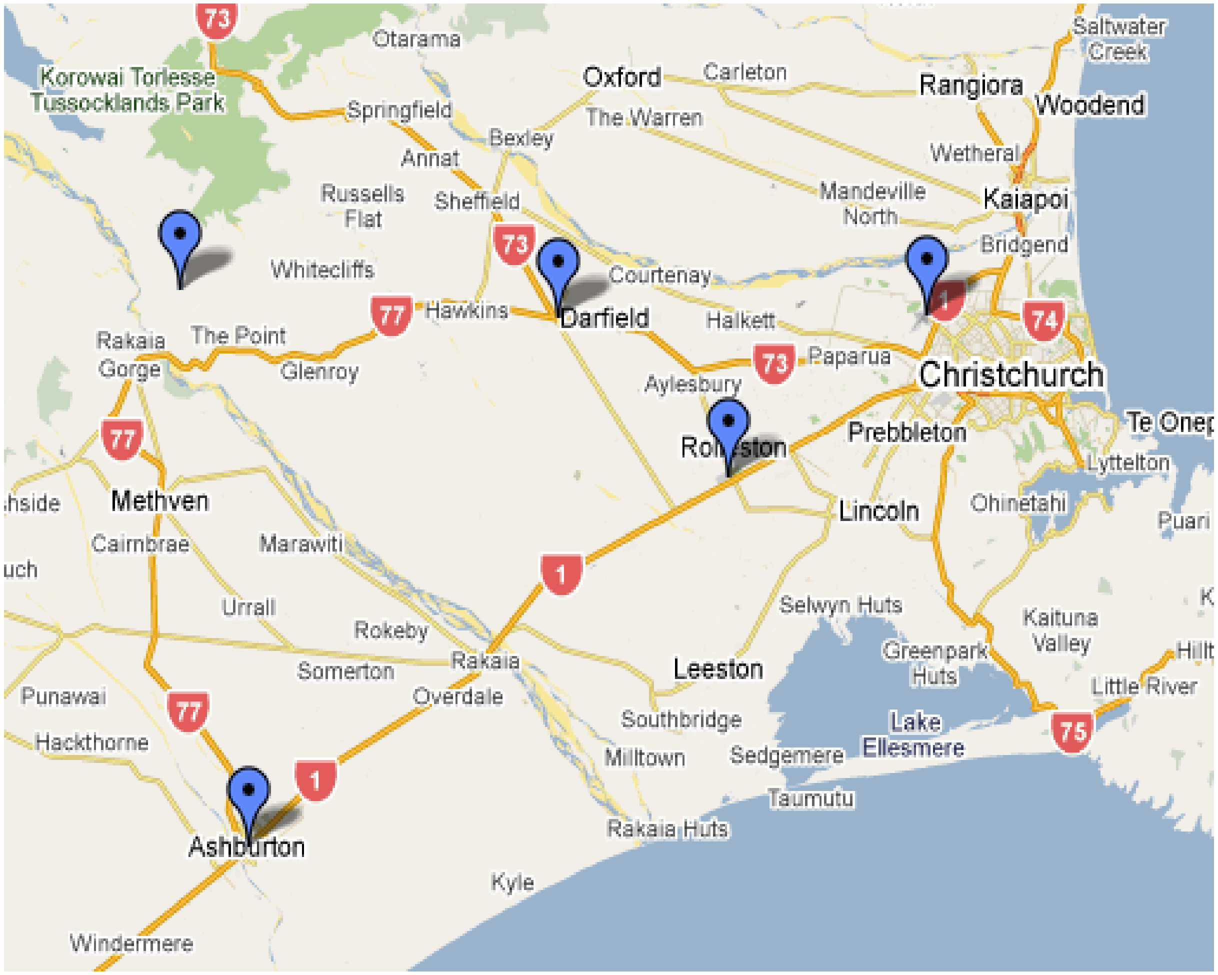
Outdoor Spatial Mapping

- Direct sensing of local variable
- In-network processing (Data fusion)
- In-Situation Real time Interaction (ability of fragmented network to operate)
- Spatial and Temporal resolution
- The system may relate to number of applications including weather monitoring, precision agriculture, ecosystem, wildfire, Wildlife, rescue missions, and others



Canterbury meteorology stations

Existing solutions



A	Darfield
B	Ashburton
C	Burnham
D	Aero
E	Snowdon
A to B	91.3Km
B to C	36.7Km
C to D	27Km
D to E	41Km

Fire Danger Rating

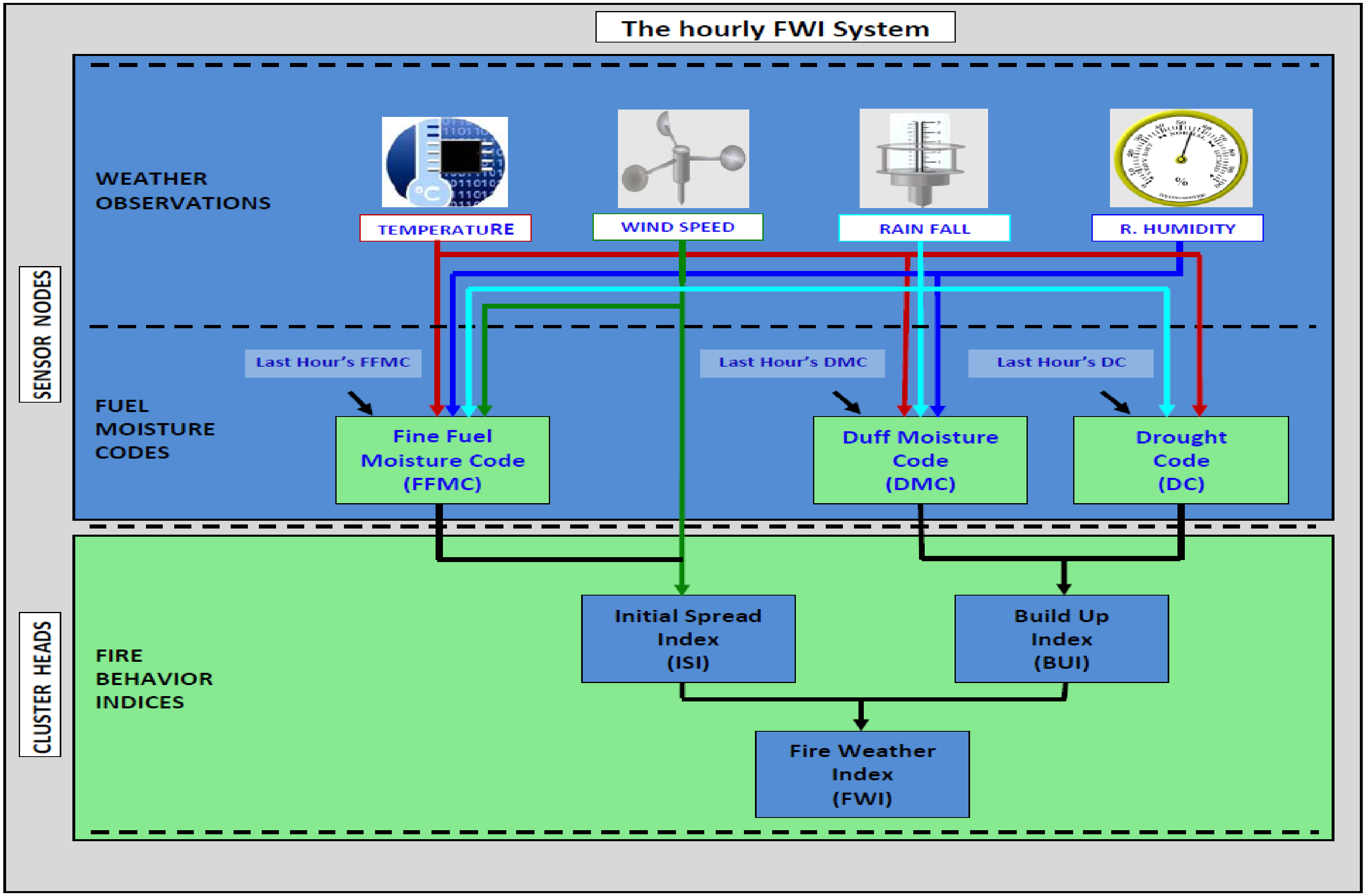
- Low FDI of 0-5
- Moderate FDI of 5-12
- High FDI of 12-31
- Very High FDI of 32-49

Severe FDI of 50-74
Extreme FDI of 75-99
Catastrophic FDI of 100+

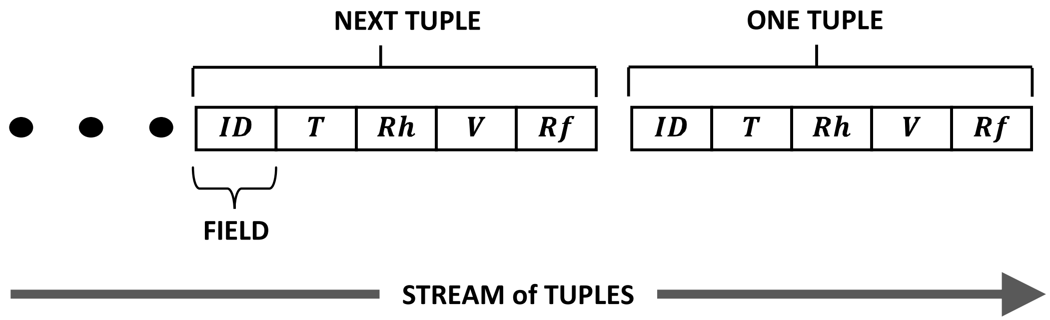
FWI bushfire hazard modelling system

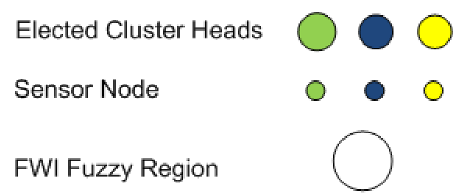
Relative ease of ignition. (**FFMC**)
Fuel consumption in moderate duff layers. (**DMC**)
Degree of smouldering in large logs. (**DC**)
Rate of fire spread. **(ISI)**
Difficulty of containing. **(BUI)**
General rating of fire intensity. (**FWI**)

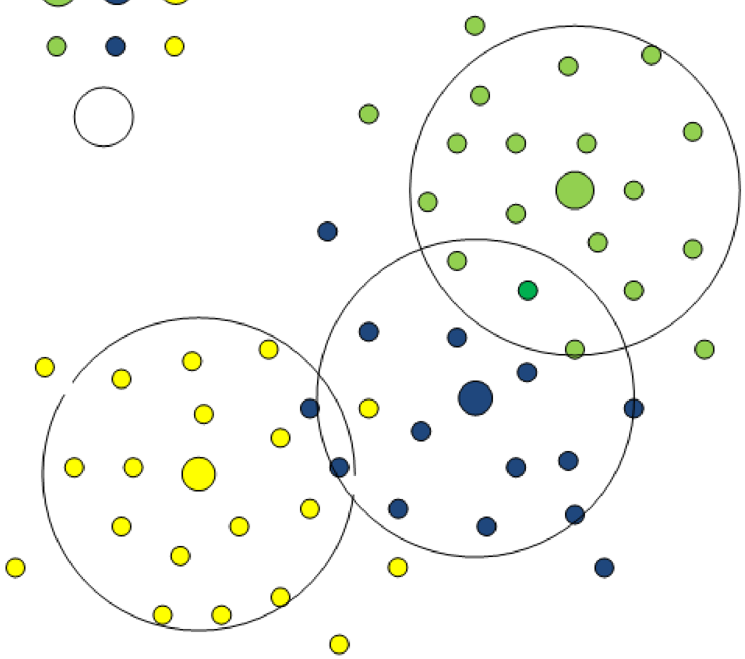
Fire Weather Index structure



Weather condition clustering





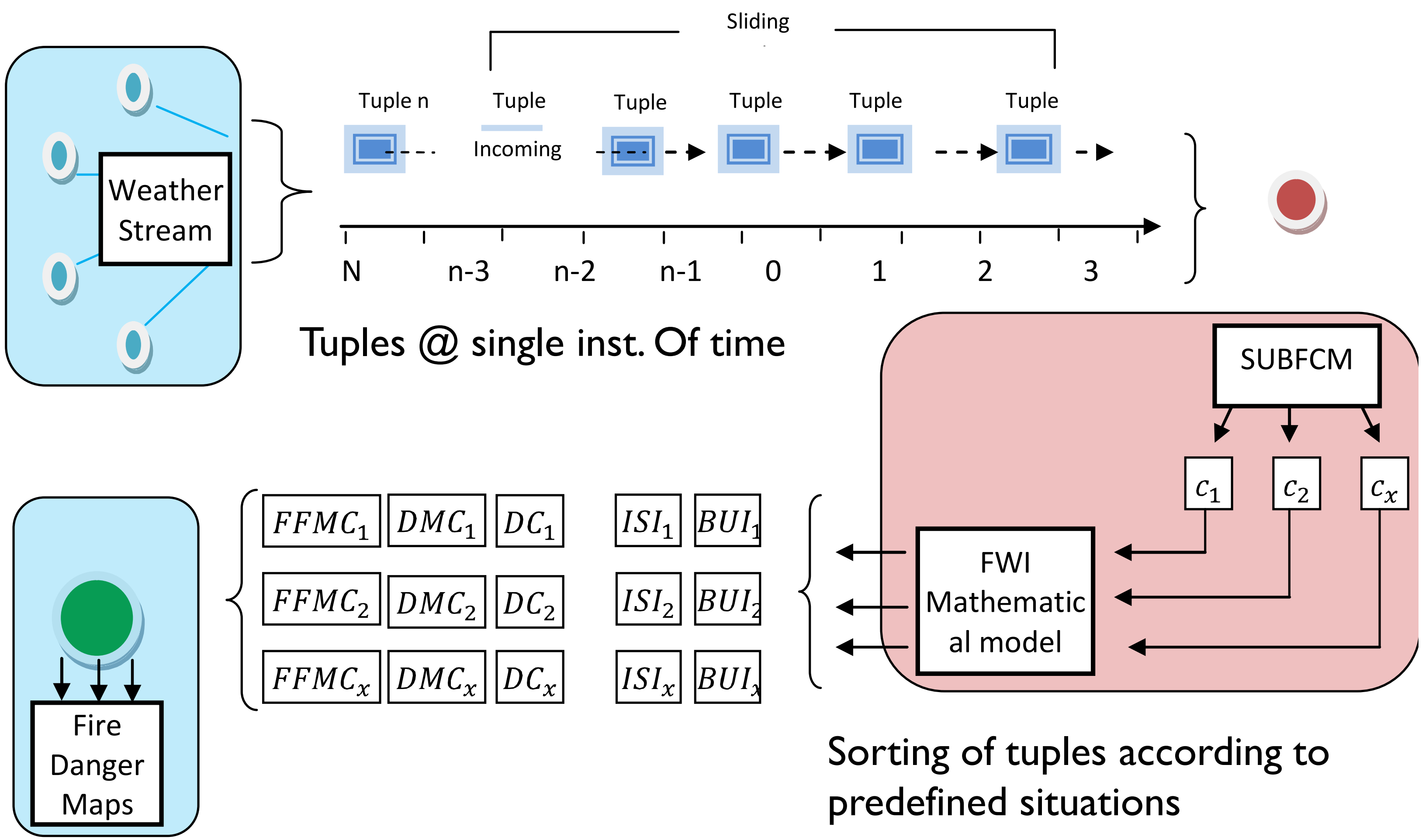


Determines the number of clusters in the data space from the input data sets

Takes the fuzzy radius and fuzziness measure as inputs and autonomously reveals the structures in the data stream space

The radius determines the granularity of the structures (Resolution against computational overhead)

Distributed weather stream mining system



Tuples @ single inst. Of time

Sorting of tuples according to predefined situations

Example Weather Data

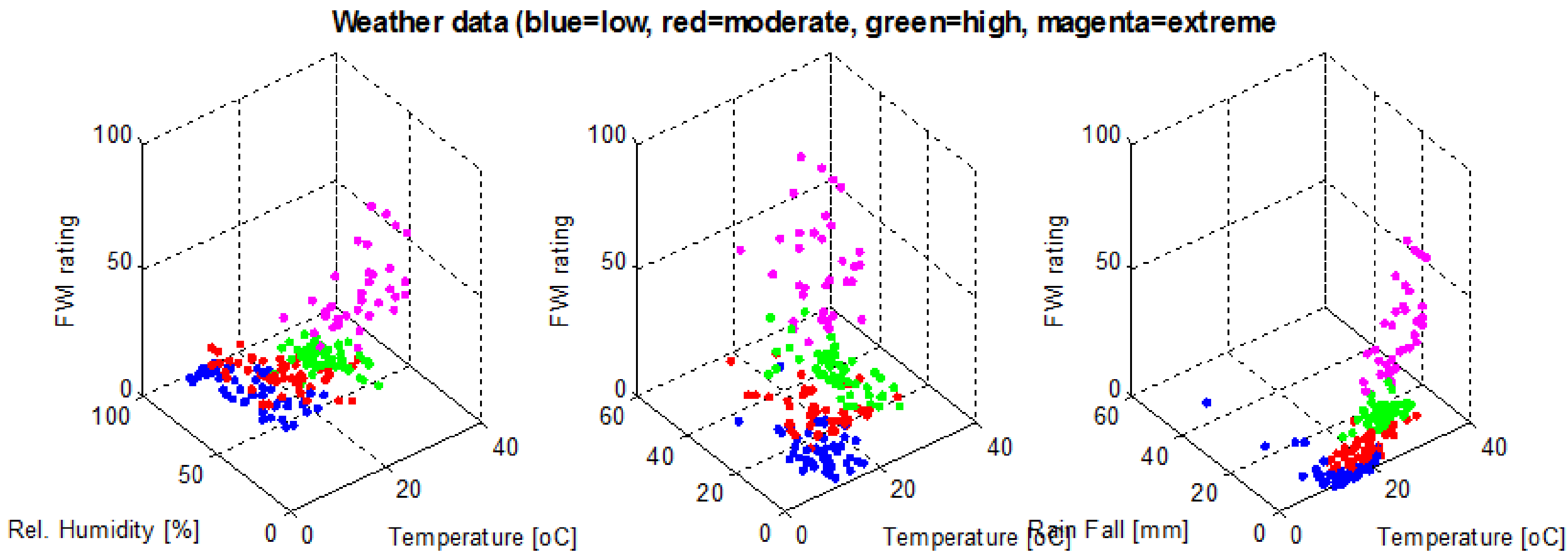
200 point were put on the test

Instance	Temperature	Rel. Humidity	Wind Speed	Rain fall	FWI	class
1	26	50	11	0	13.65	M
2	14.1	89	14.9	0	6.938	M
3	26.9	37	16.4	0	19.57	H
4	15.6	78	18.5	0	12.55	M
5	26.1	32	39.8	0	57.63	E
6	10.9	76	12.9	5.2	0.629	L
7	18.4	55	28.8	0	10.64	M
8	20.4	43	45.3	0	42.23	E
9	26.8	40	35	0	42.05	E

Cluster centers:

C1	13.9	76.62	4.1	3.97
C2	17.53	64.38	21.37	0.435
C3	21.28	46.69	21.36	0.136
C4	24.05	33.55	32.26	0.334

Example of SubFCM On Weather Data



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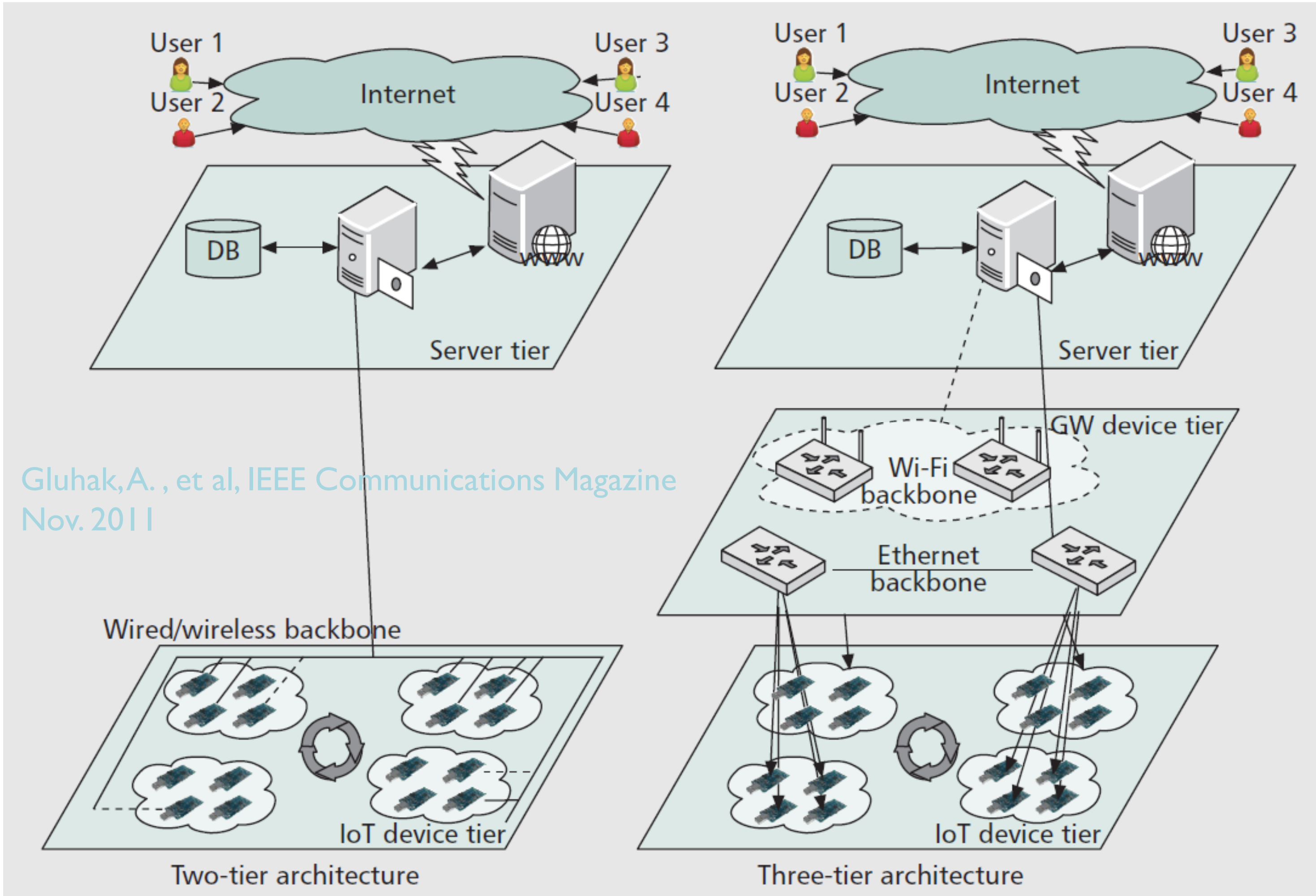
Sensor Network Testbeds

WSN Testbeds provide a way of testing network architecture and domain applications in an environment that makes it easy to

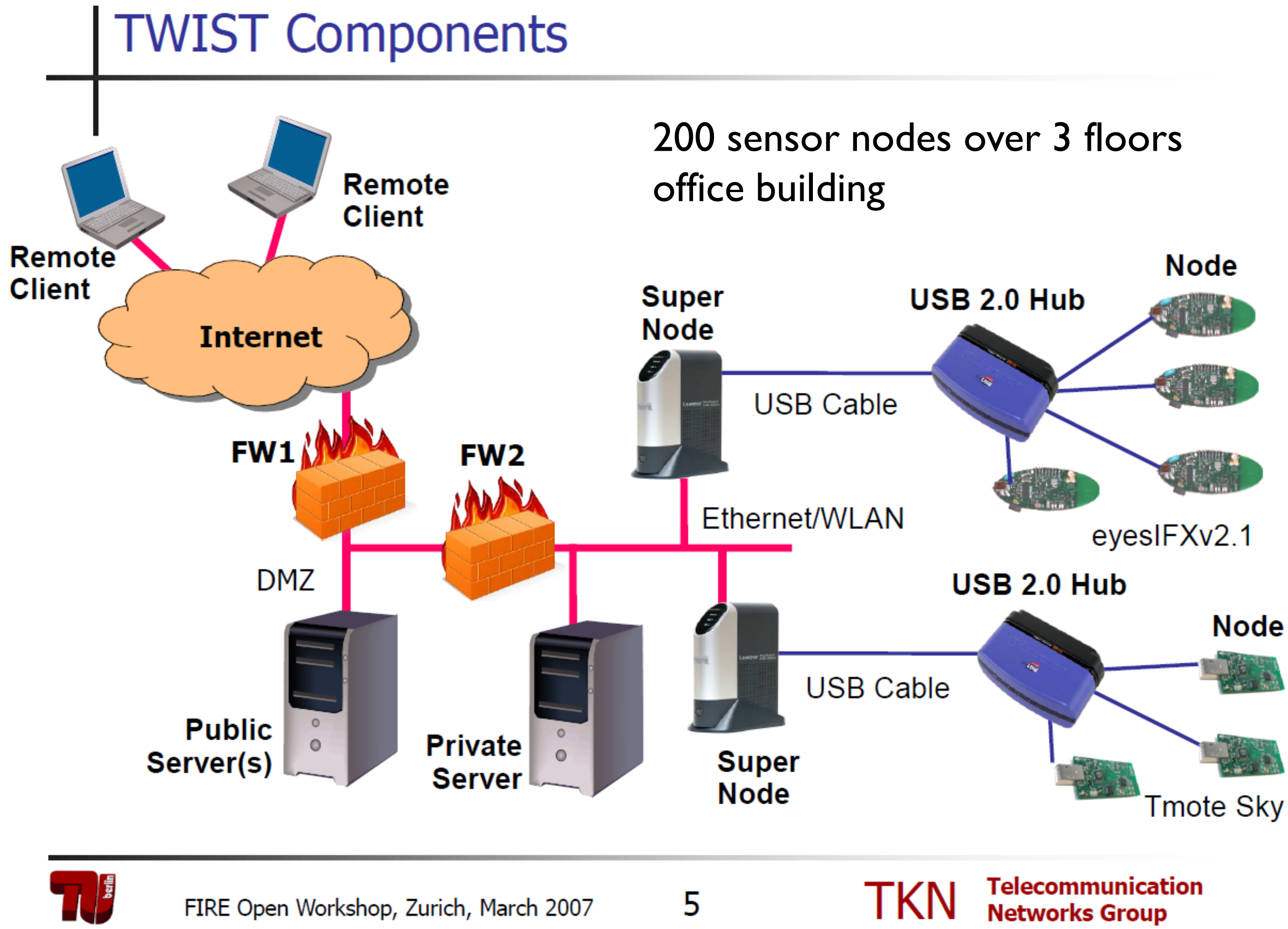
- Deploy experiments,
- Configure them statically or dynamically, and
- Gather performance related information.

Testbeds Organization



Gluhak, A. , et al, IEEE Communications Magazine Nov. 2011

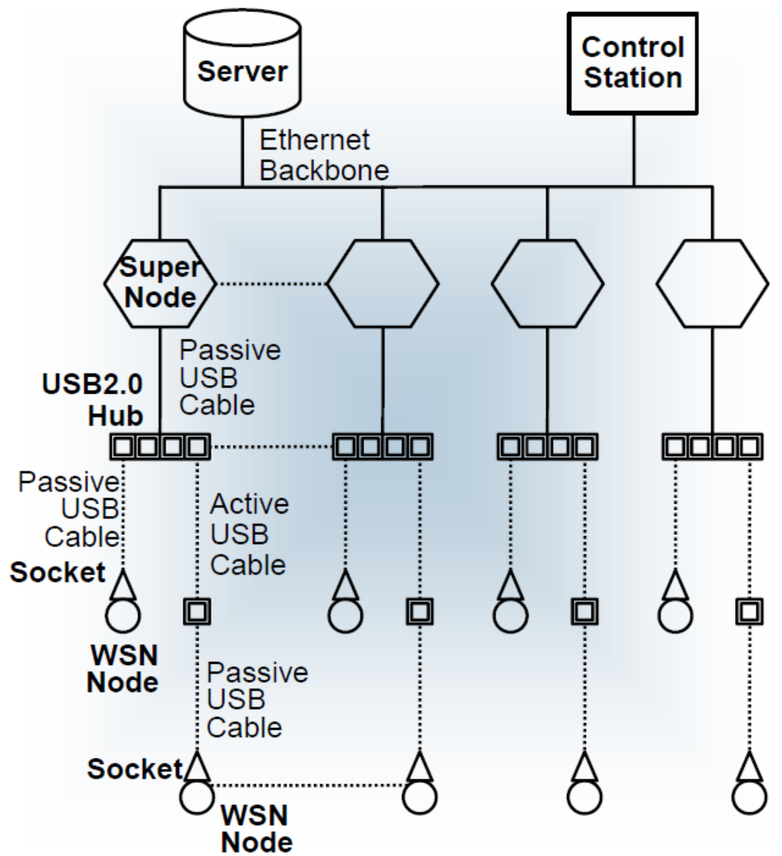
TUB Exercise



TWIST

TWIST Architecture

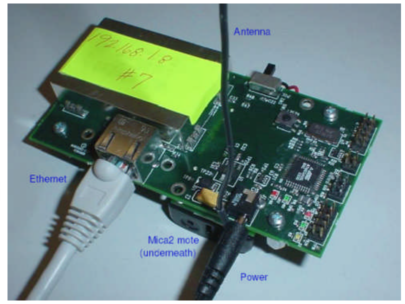
TKN
Wireless
Indoor
Sensor network
Testbed



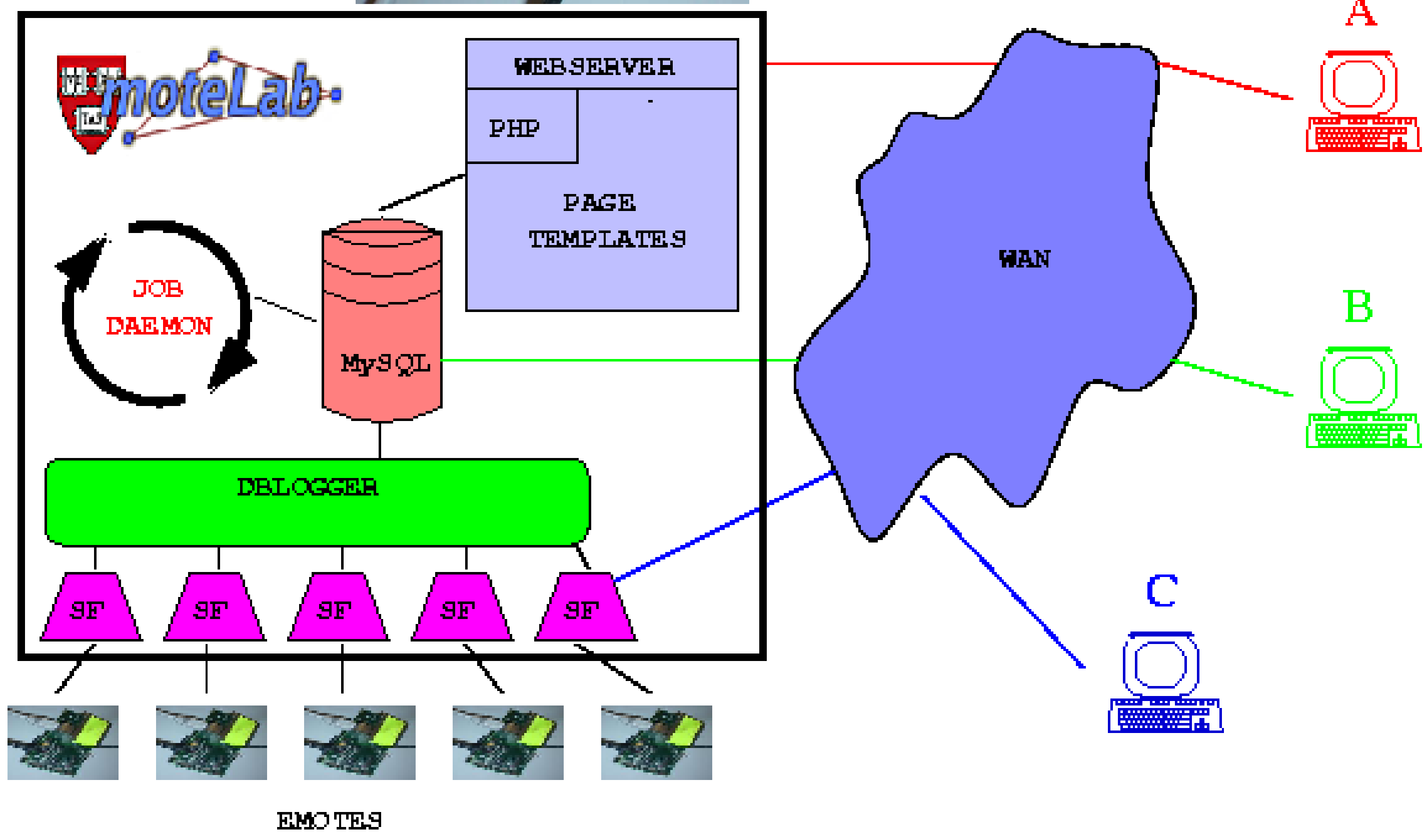
FIRE Open Workshop, Zurich, March 2007 4

TKN Telecommunication Networks Group

MoteLab_ Harvard

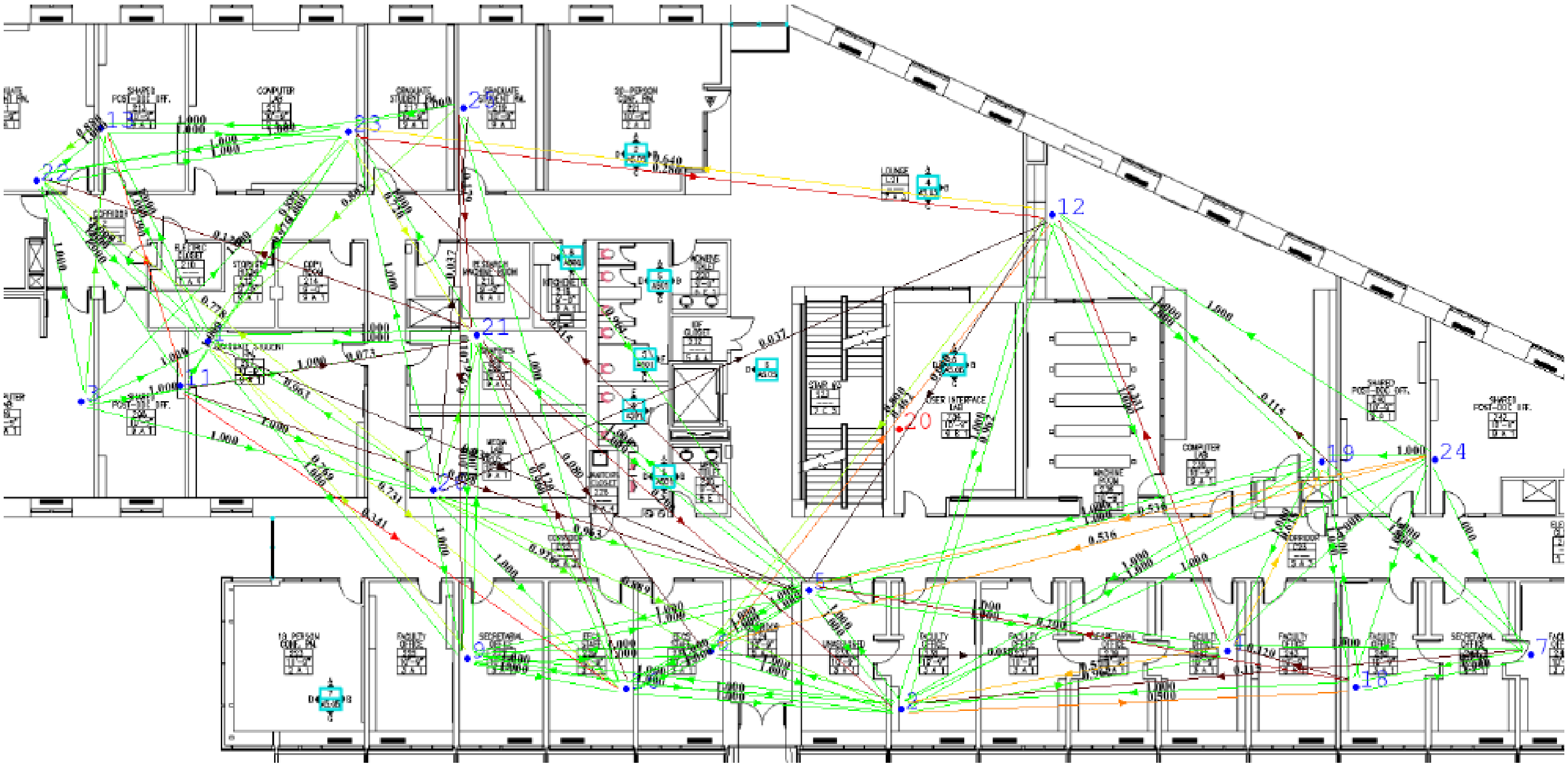


http://motelab.eecs.harvard.edu



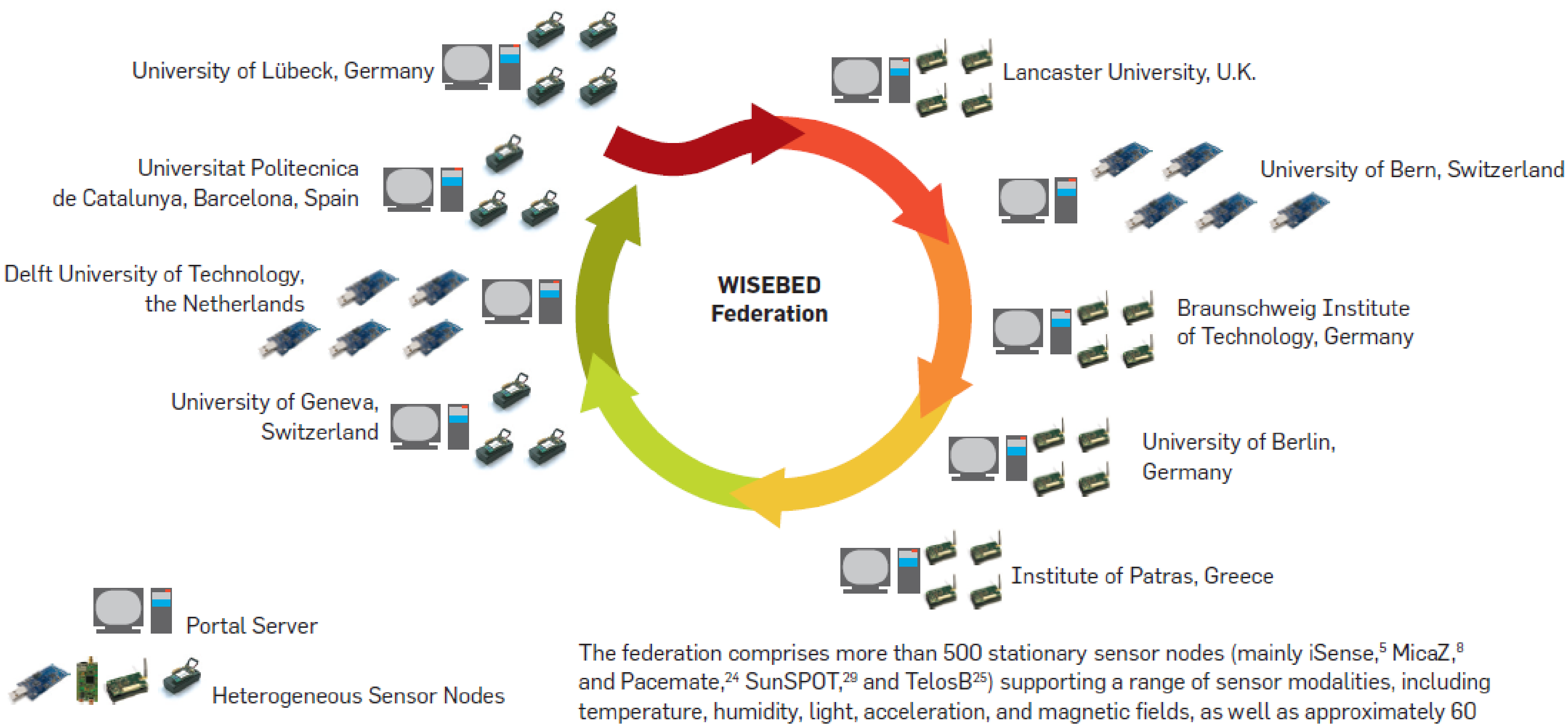
Motes Distribution

http://motelab.eecs.harvard.edu



WISEBED Exercise

Flexible Experimentation in Wireless Sensor Networks, communications of the acm | January 2012 | vol . 55 | no. 1

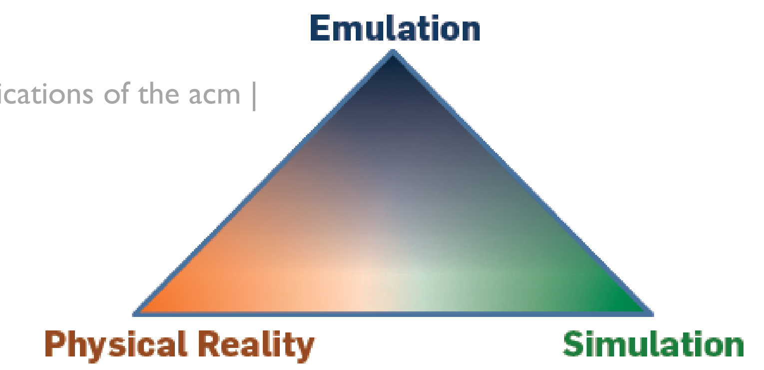


The federation comprises more than 500 stationary sensor nodes (mainly iSense,[5] MicaZ,[8] and Pacemate,[24] SunSPOT,[29] and TelosB[25]) supporting a range of sensor modalities, including temperature, humidity, light, acceleration, and magnetic fields, as well as approximately 60 mobile sensor nodes and 40 outdoor nodes. Each site offers a "portal server" that exposes its capabilities to the outside world through an iWSN interface. Most sites also contribute one or more simulator engines running simulated parts of VTBs.

Mixed Representations

Flexible Experimentation in Wireless Sensor Networks, communications of the acm | January 2012 | vol . 55 | no. 1

Three-cornered testbed design space for WSN experimentation.



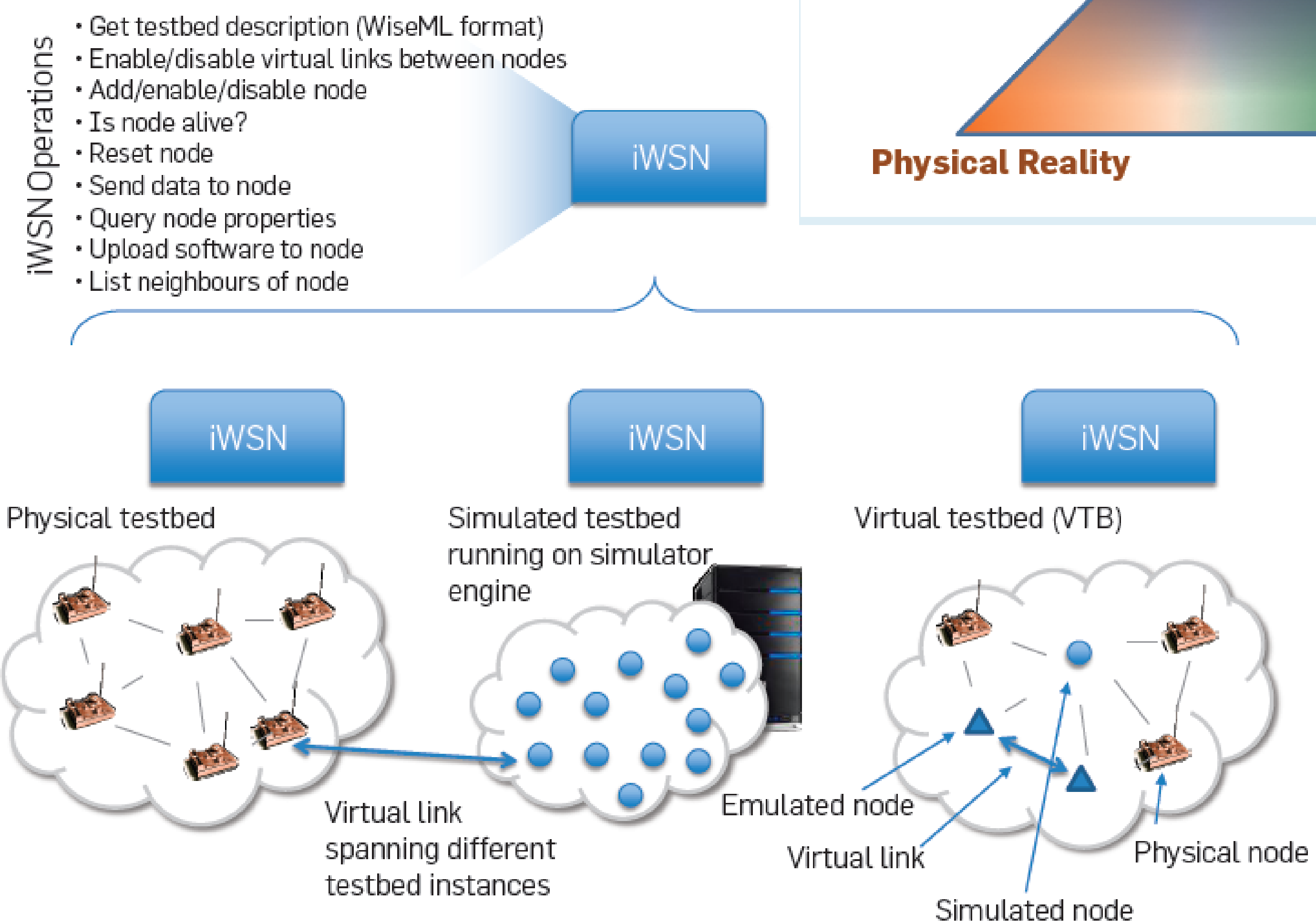
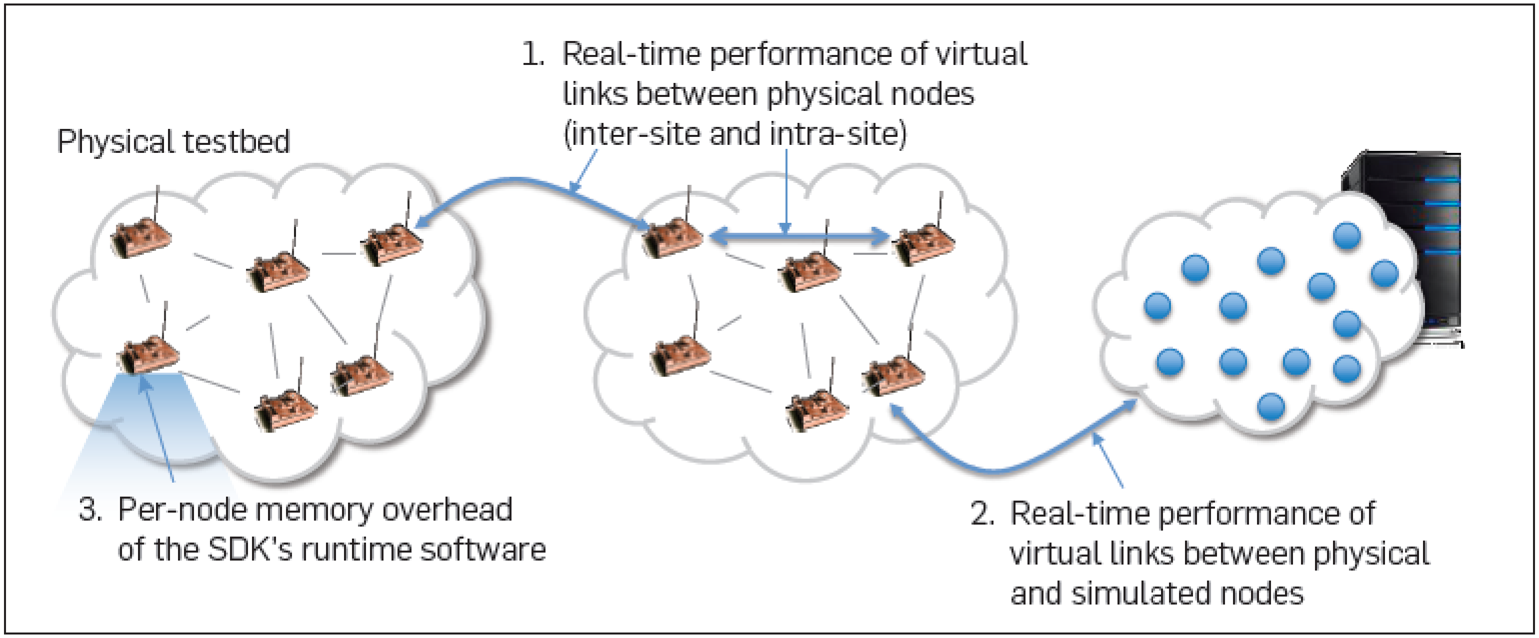


Table 1. Message latencies in virtual links under various scenarios; results are averaged over more than 1,000 messages in each case.

Flexible Experimentation in Wireless Sensor Networks, communications of the acm | January 2012 | vol . 55 | no. 1

Hardware/OS	Physical Radio	Intra-site	Inter-site
ScatterWeb/TinyOS	75ms	5ms	53ms
TelosB/Contiki	40.2ms	5ms	53ms
iSense/iSense	7ms	5ms	53ms



The Wiselib

- The Wiselib is...
  - a library of re-usable code (just like the C++ STL)
  - a development framework and API
  - platform-independent (almost all WISEBED architectures)
  - implemented using C++ templates

- The Wiselib is not…
  - a new type of middleware

- The Wiselib contains...
  - a collection of algorithms
  - an abstraction of WSN operating systems
  - utility functions and data structures (pSTL, pMP)

WISEBED – Wireless Sensor Network Testbeds – http://wisebed.eu

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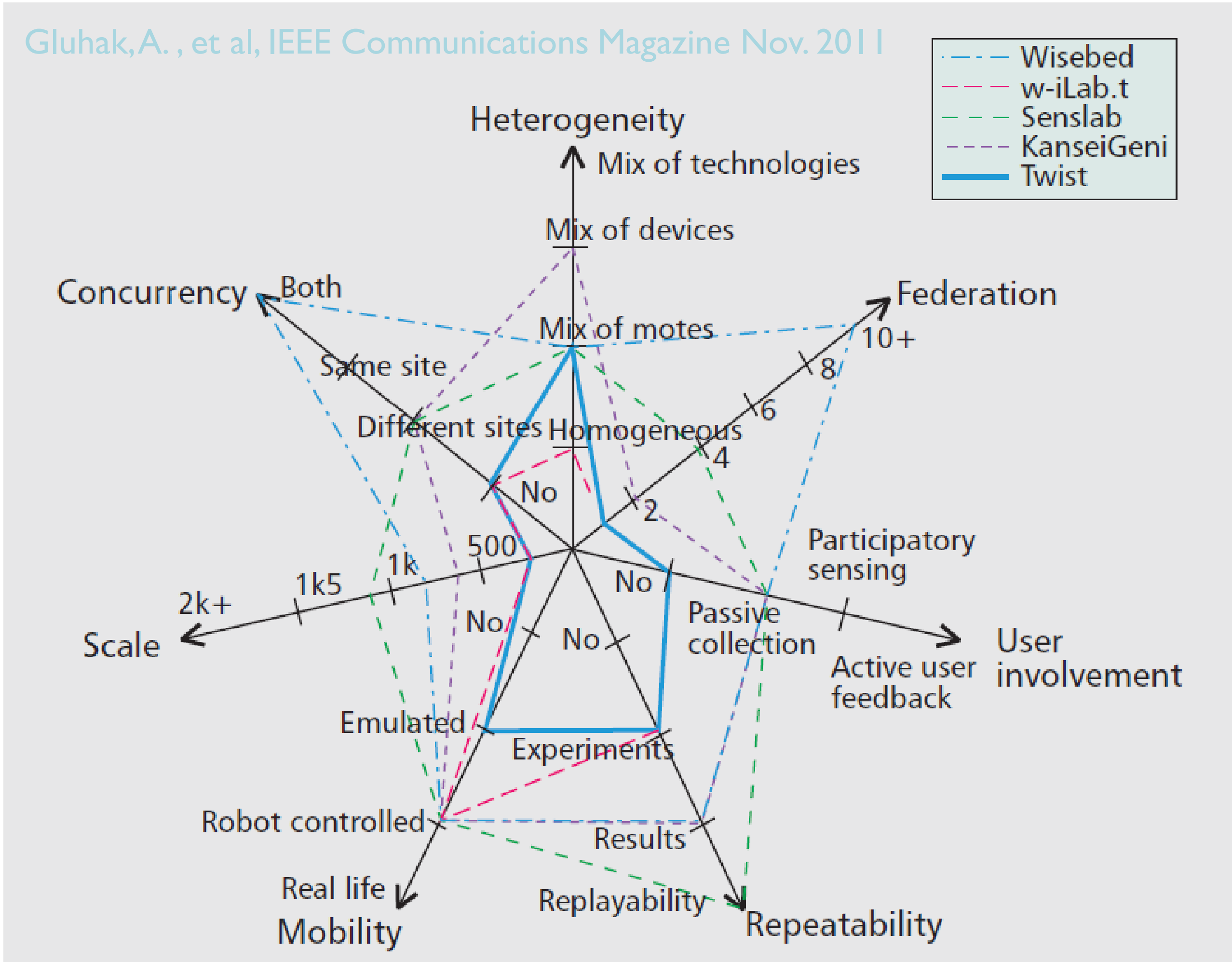
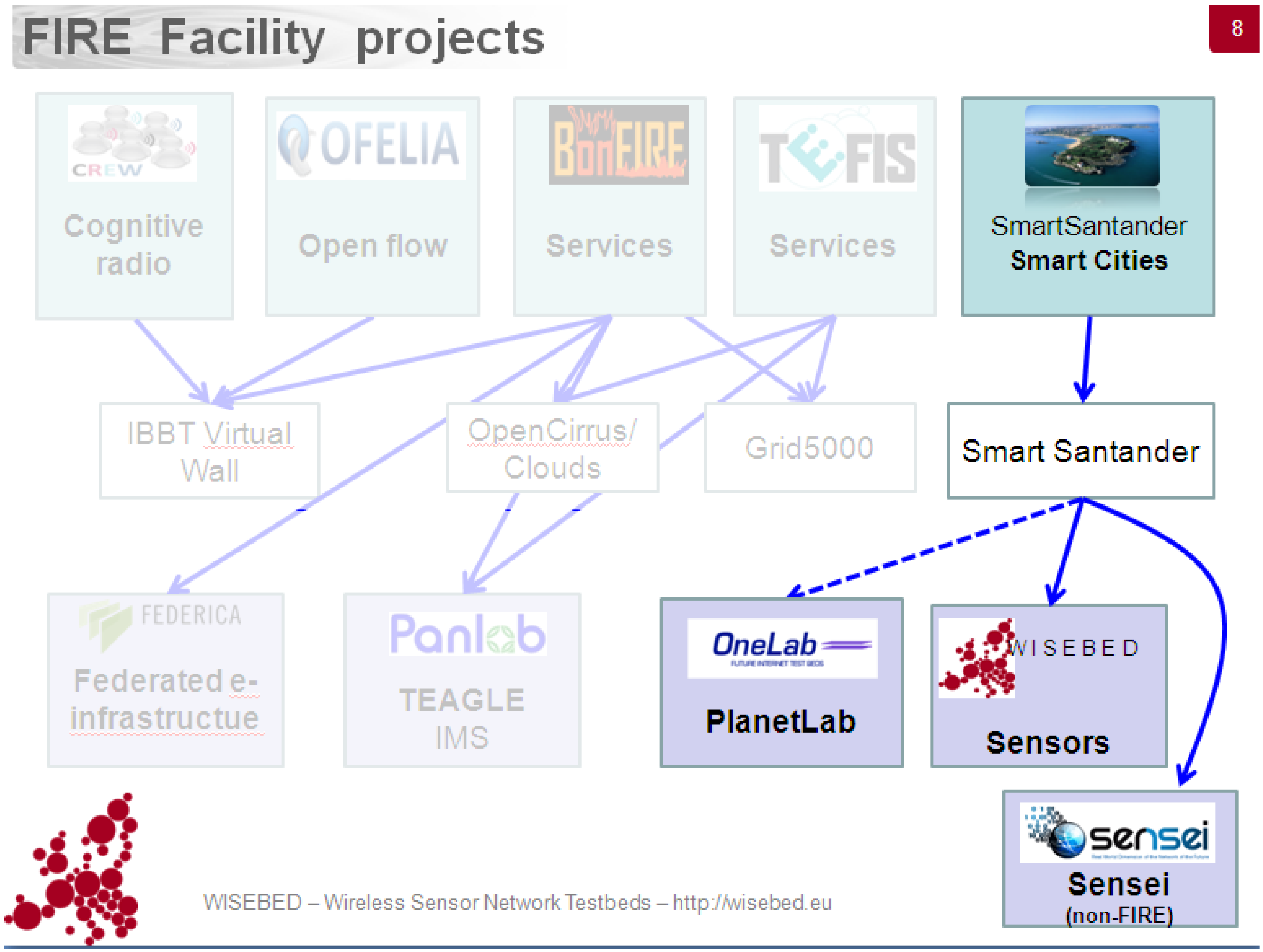
Federated Testbeds

- Federated testbeds present another level of involvements and offers the followings:
  - An evolving mechanism for seamless integration of multiple autonomous testbeds of homogeneous or heterogeneous entities
  - A scalable approach to establish large-scale (geographically distributed and diverse) realistic testbeds
  - Primary objective: to enable researchers to conduct a single experiment across federated testbeds
- Example: a topology of 300 nodes with 100 from motelab/ Harvard, 100 from TWISTtestbed/TUB, and the remaining 100 from an Asian testbed

Testbed Performance Measures



FIRE Project



Ambition

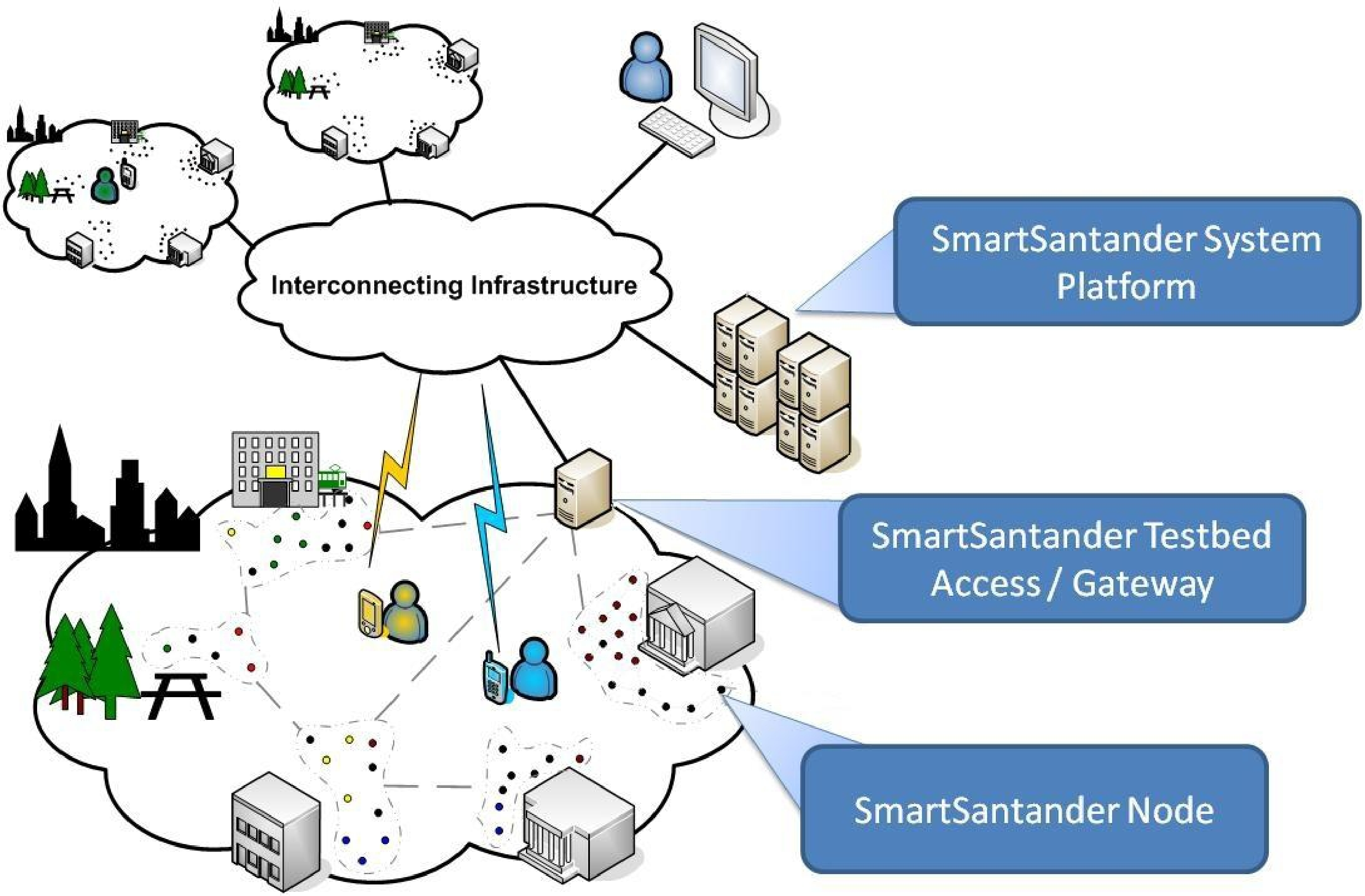
9

Smart Santander

- Built on top of SENSEI and WISEBED technologies
- Objectives
  - To build a **unique-in-the-world city-scale experimental research facility** in support of typical applications and services for a Smart City
  - More than **20,000 sensors** based on a real life Internet of Things deployment **in an urban setting**
  - www.smartsantander.eu

WISEBED – Wireless Sensor Network Testbeds – http://wisebed.eu

Smart Santander



Talk Overview

- Sensor Network Background
- Example Applications
  - Smart Farming
  - Spatial Mapping
- Sensor Network Testbeds
- Vision for the Federation
- **Other Related Technologies**
- Other Remarks & Conclusions

The Internet of Things is …

"SAP IOT Definition". SAP Research. Retrieved 2011-03-18

'A world where physical objects are seamlessly integrated into the information network, and where the physical objects can become active participants in business processes.

Services are available to interact with these 'smart objects' over the Internet, query and change their state and any information associated with them, taking into account security and privacy issues.'

RFID, Sensor Networks etc. are just enabling technologies!

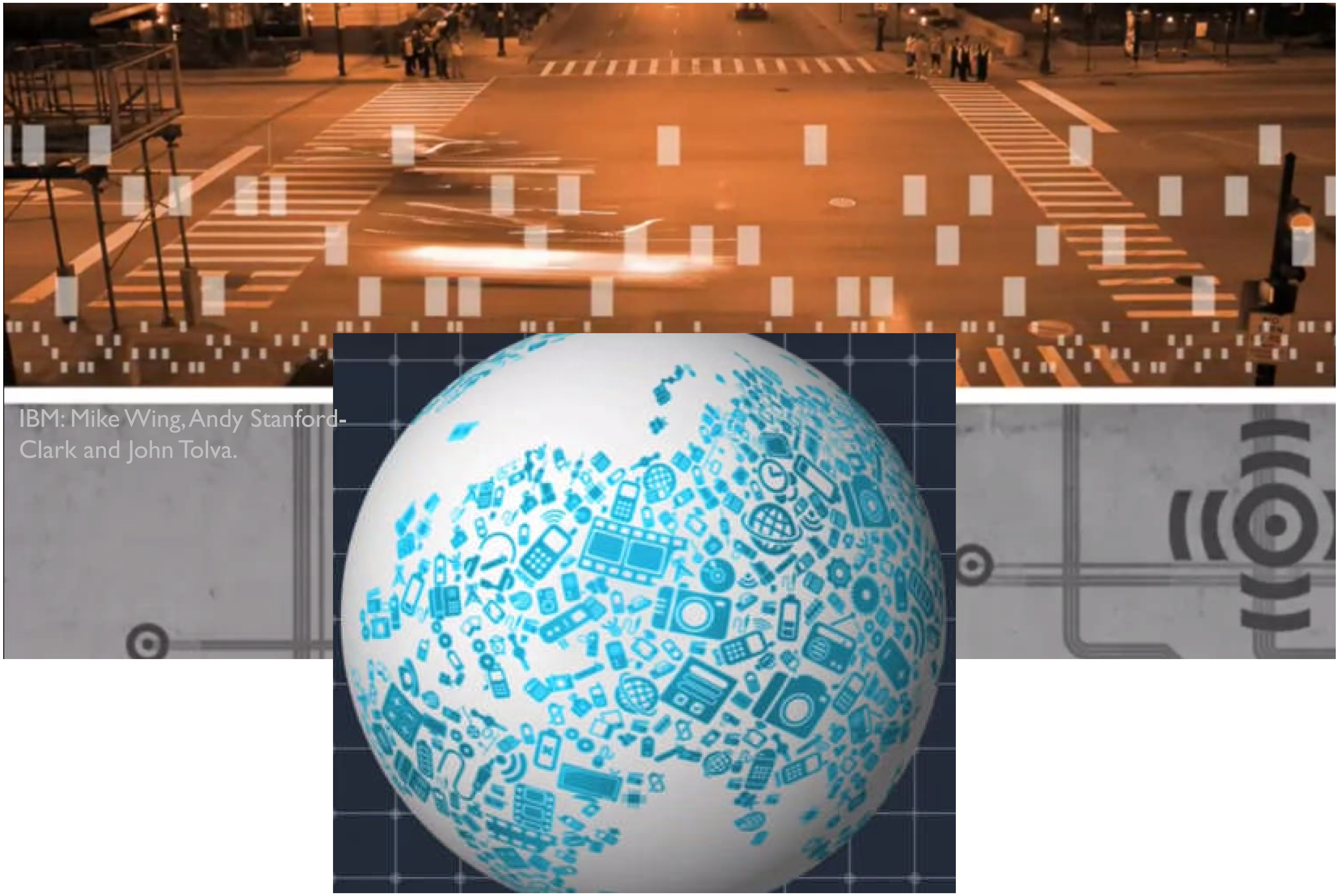
Future Internet

FISO

http://www.youtube.com/watch?v=sfEbMV295Kk

IBM: Mike Wing, Andy Stanford- Clark and John Tolva.

Vision for the Internet of Things



IBM: Mike Wing, Andy Stanford-Clark and John Tolva.

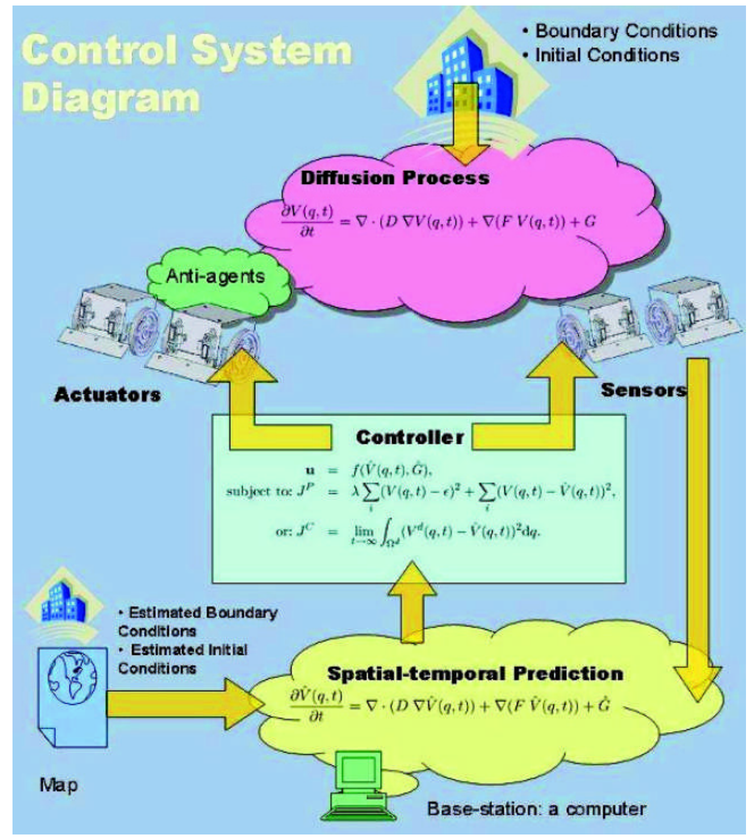
Cyber-Physical Systems

Optimal Observation for Cyber-physical Systems, Springer, e-ISBN 978-1-84882-656-4

- Computational thinking and **integration of computation around the physical dynamic systems** form CPSs where sensing, decision, actuation, computation, networking, and physical processes are mixed.

• Dynamic evolutions happen not only along the **time axis** but also along **spatial axes**.

Due to the complexity of the problems, it is usually very difficult to **balance the tradeoffs** by heuristic or ad hoc methods. For example, **energy costs and estimation precision** are counteractive under certain cases, in terms that putting too many sensors in the dormant mode may save precious onboard energy but also nullify the observation



CPS

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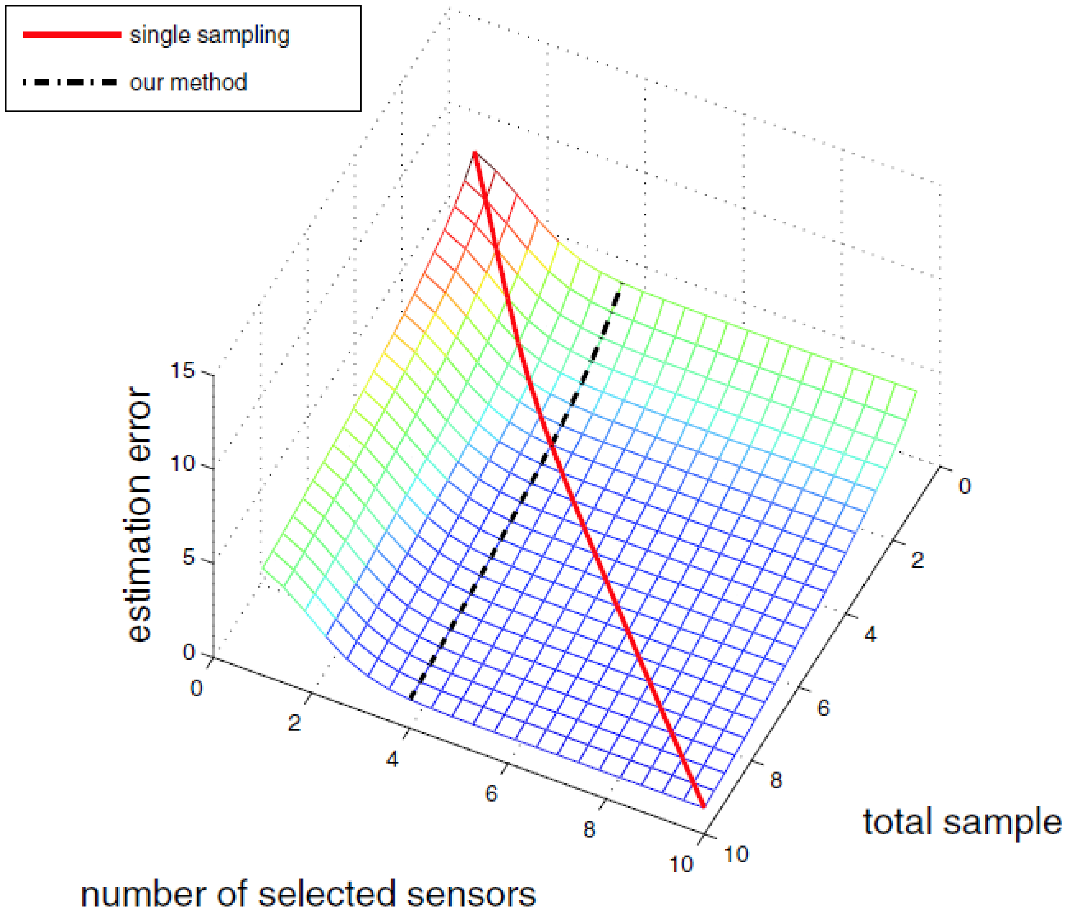


In the event of fire it is first necessary to accurately establish the location of the event before turning the sprinkler

Reality Mining: MIT Media Lab

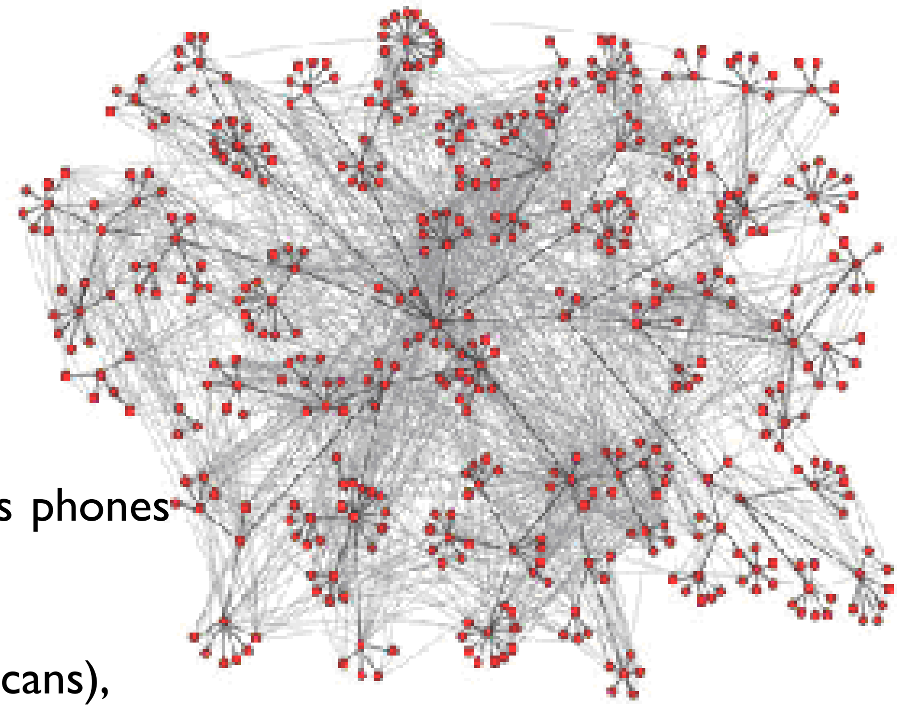
http://reality.media.mit.edu/

Developing technology for sensing through mobile phone applications

Looking into human behavior social network

Collected datasets may be used by wide range of fields including:

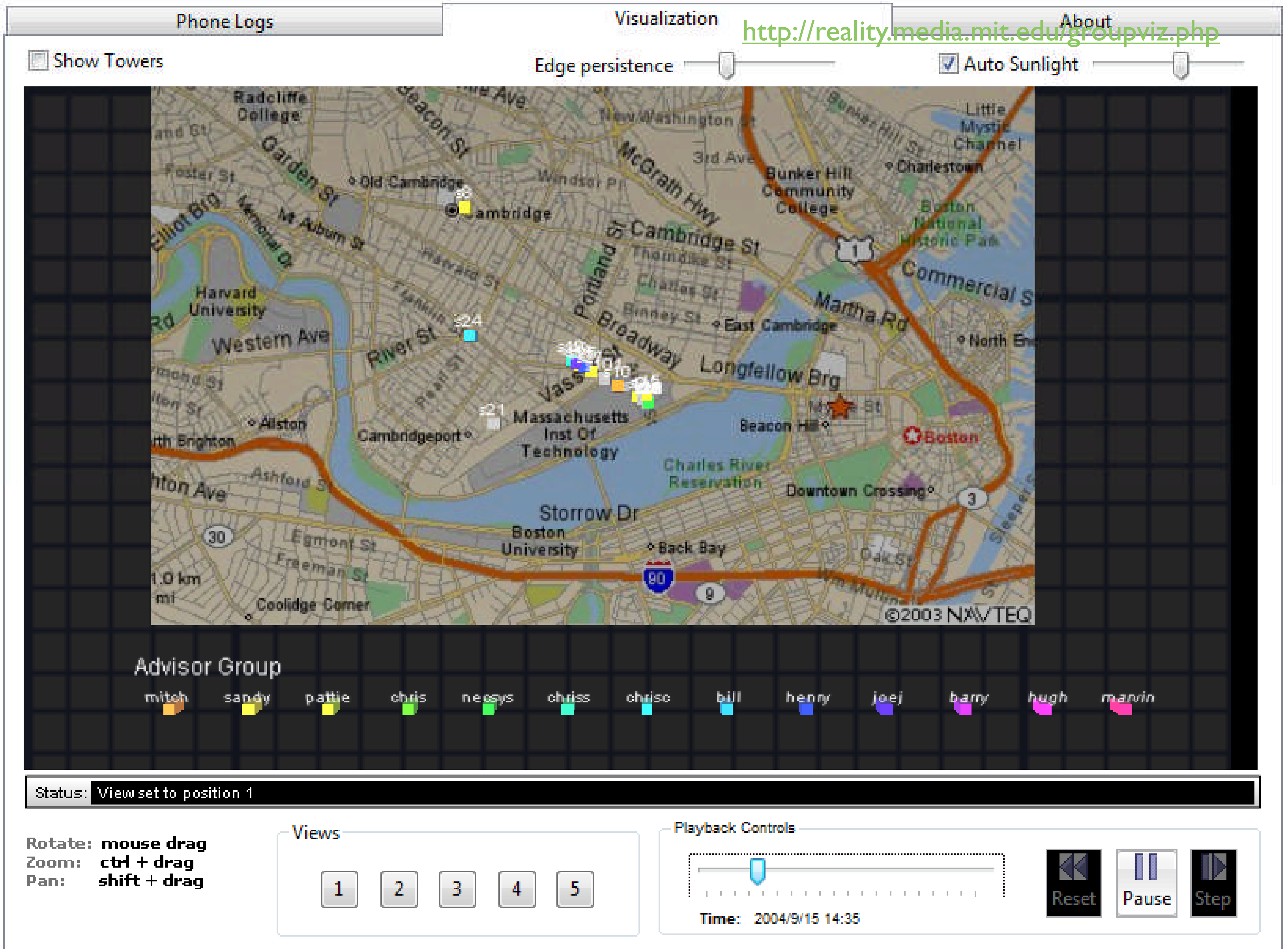
- epidemiology,
- sociology,
- physics,
- artificial intelligence, and
- organizational behavior



The information available from today's phones includes:

- user's location (celltower ID),
- people nearby (repeated Bluetooth scans),
- communication (call and SMS logs), as well as
- application usage and phone status (idle, charging, etc).

Reality Mining: Group Behavior



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Integrating Multiple Physical Beds

Dynamic complex system that concurrently interact with multiple processes and deliver timely services at a predefined QoS

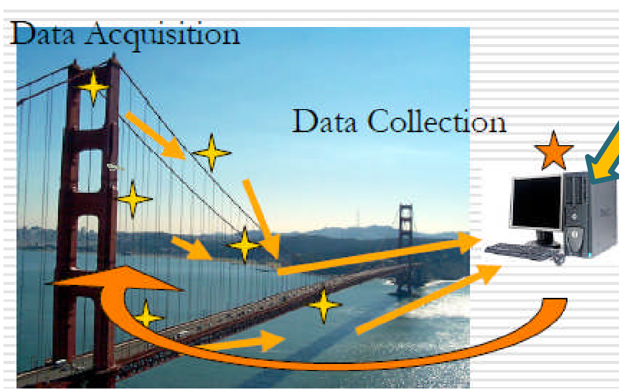
User

User

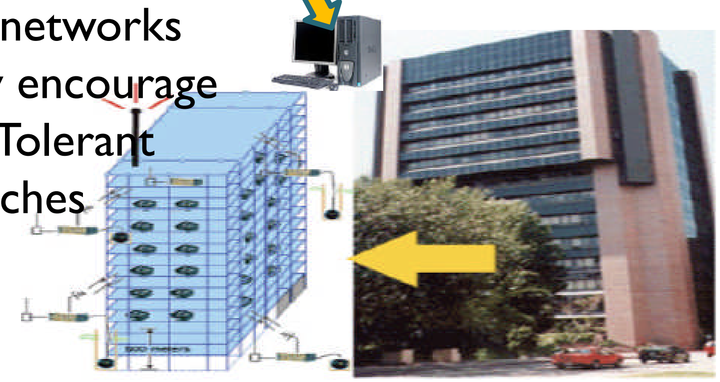
User

Cost factors like level of complexity, energy involvement, delay tolerance, security and others would be the parameters for optimization

Network Characteristics?
End-to-End, Criticality, Bandwidth, Interactivity, Delay Tolerance, Network Dimension,



Diversity among networks technologies may encourage the use of Delay Tolerant networks approaches



Parties Involved

- **Sensor/ Actuator Level (point of measurement/ Actuation)**: Precession, Accuracy, Real-time Response, measurement/ actuation errors, etc
- **Cluster Level (Physical Sub-pace)**: Ability to interact with sensors/ actuator and capture/ influence the phenomena, coverage (spatio-temporal), exposure, and number of active sensors/ actuators
- **Network Level (overall physical space)**: latency, delay, and packet loss, application requirements including energy cost
- **Federation Level**: reservation based and reservation-less, Policies like admission control, traffic classes, policy managers, and queuing mechanism,
  - different traffic streams should be treated in different ways, inter-arrival time, packet delay, latency or round-trip rate and cumulative distribution function of the RTT

Conclusions

- Sensor Networks (SN) and the Internet are facilitating the key instruments for integrating the physical world and paving the way towards what is called the planet nervous system
- Good number of technologies like IoT, Reality Mining, CPS, and others are contributing to the details of this integration
- Significant number of SN testbed initiatives are playing important role in accelerating the evolution of the technology around federating multiple physical spaces
- As we move forward, impact on both the planet and living species need to be carefully considered

Thank You For Your Attention

Any Questions, thoughts, …?

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