Toward Internet of Everything: IoT, CPS, and SNSS

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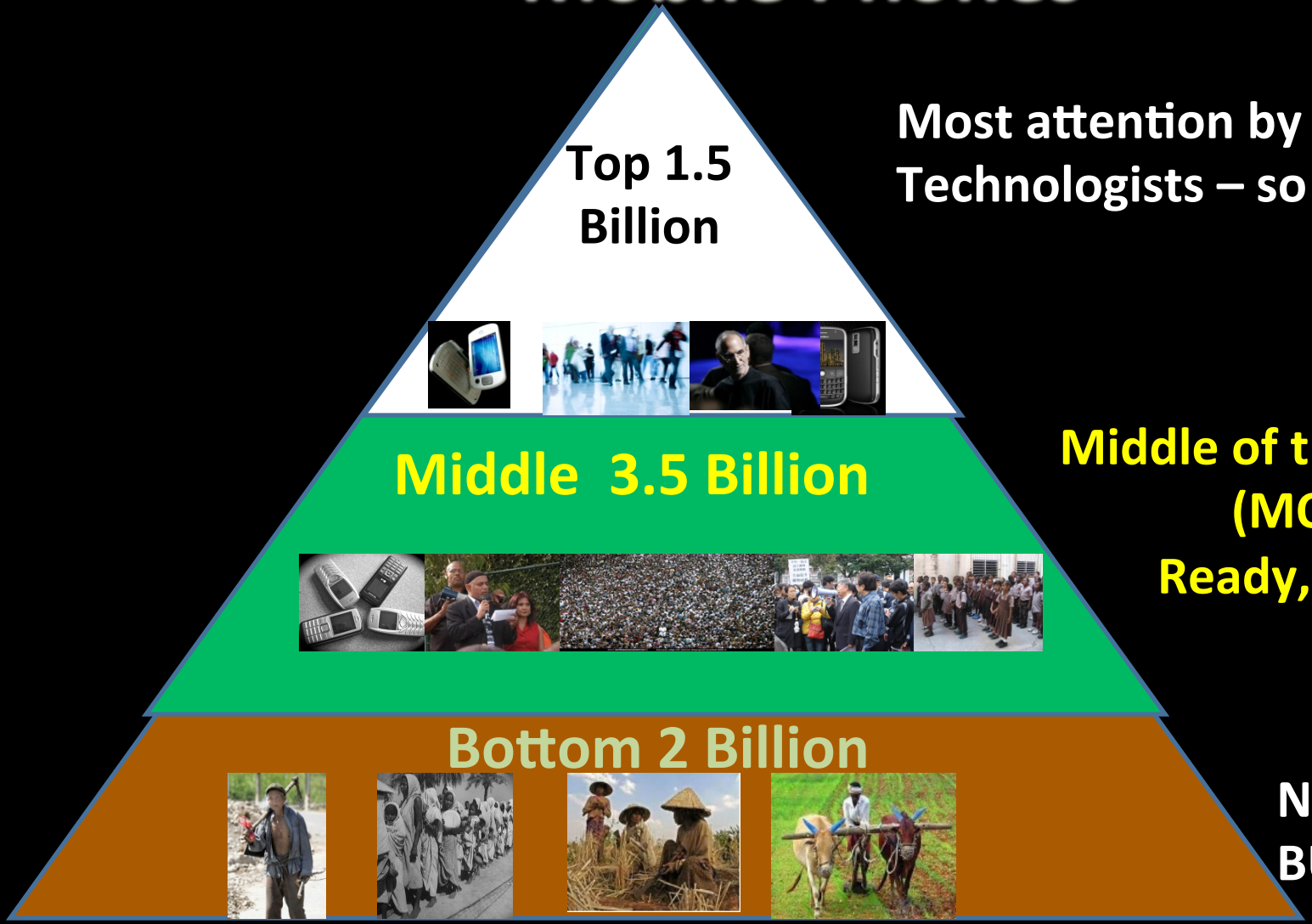
Outline

- IoT, CPS, CPSS, SNSS: Some Thoughts
- IT Challenges
- NIST Activities in CPS, IoT, and SNSS
- SNSS in Action
- Summary

Technology Trends

1. Ubiquitous mPCDs and other wearable devices

The World as seen through Mobile Phones



Most attention by Technologists – so far.

Middle of the Pyramid (MOP): Ready, BUT …

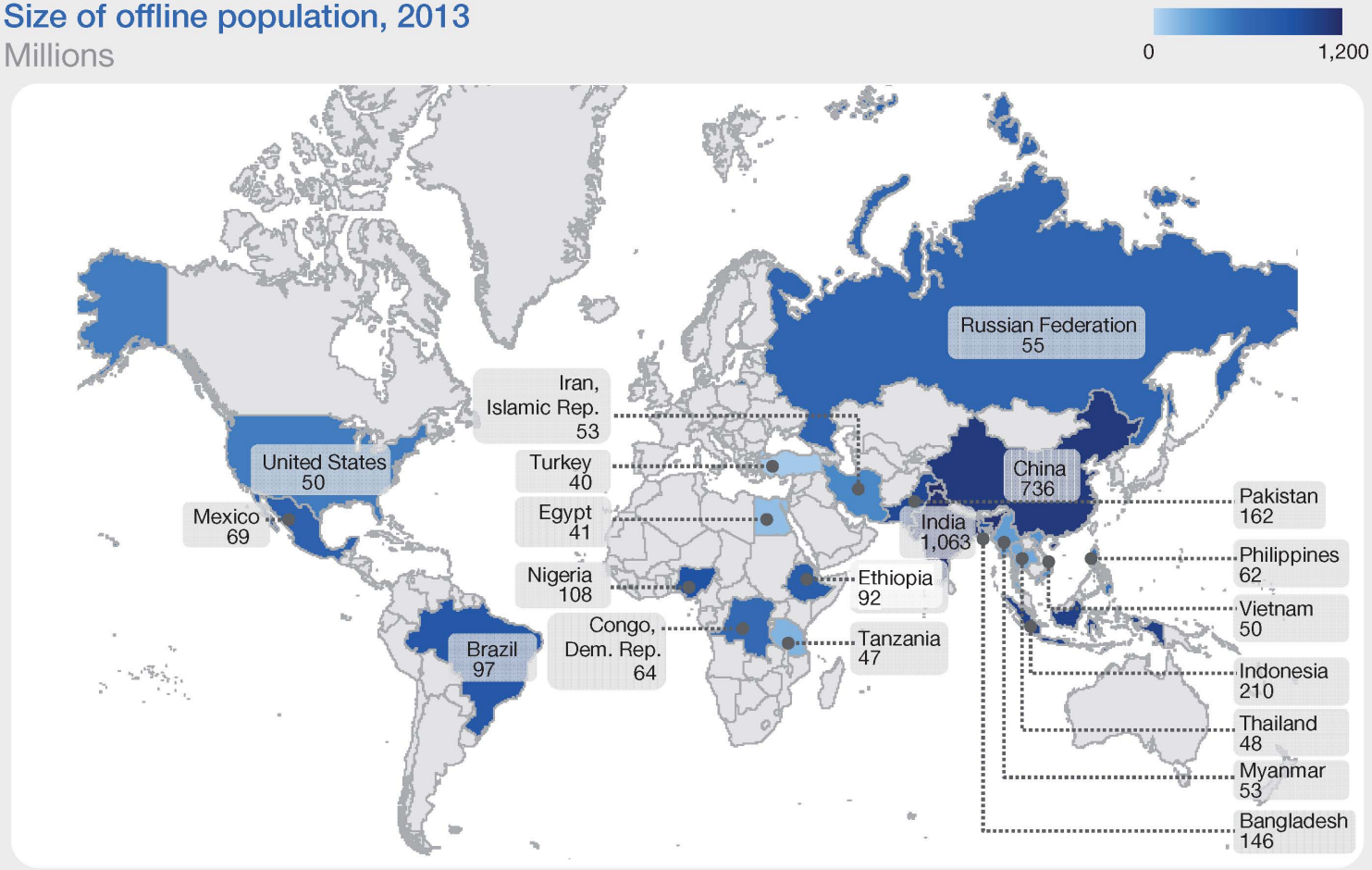
Not Ready, BUT….

Courtesy: Ramesh Jain, UCI

20 countries account for 3.2 billion offline individuals, ~75% of the 4.4 billion non-Internet users worldwide

Size of offline population, 2013

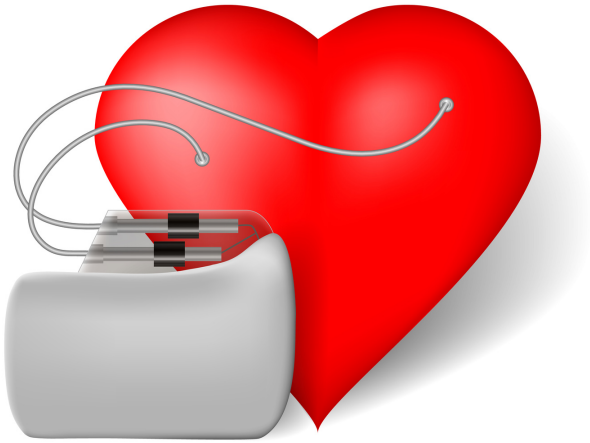
Millions

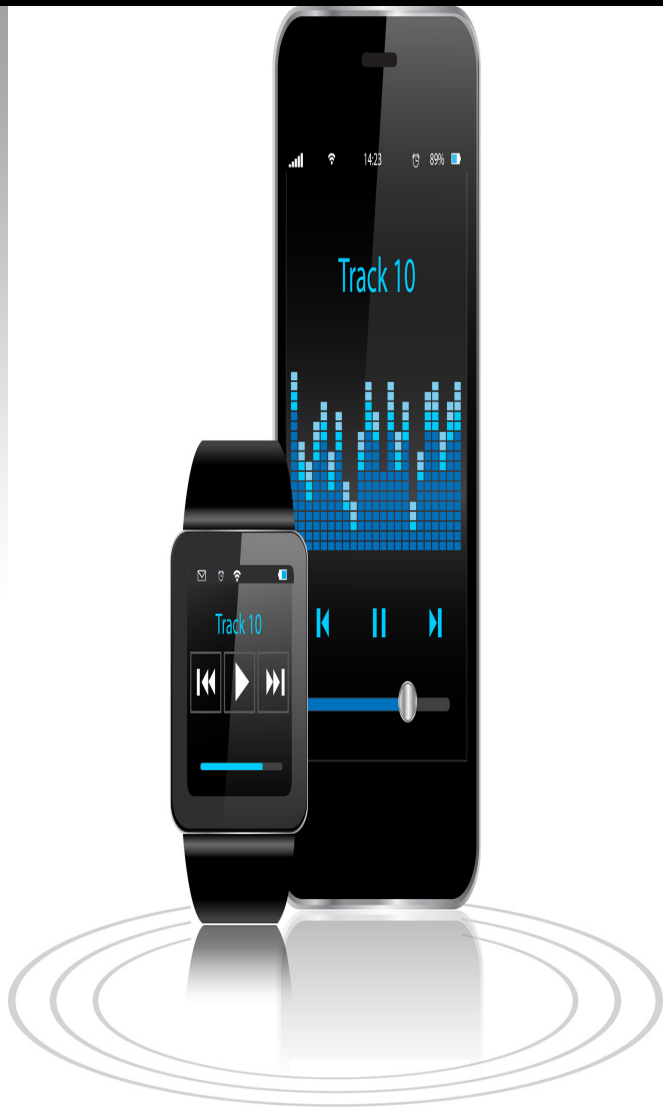


SOURCE: The World Bank

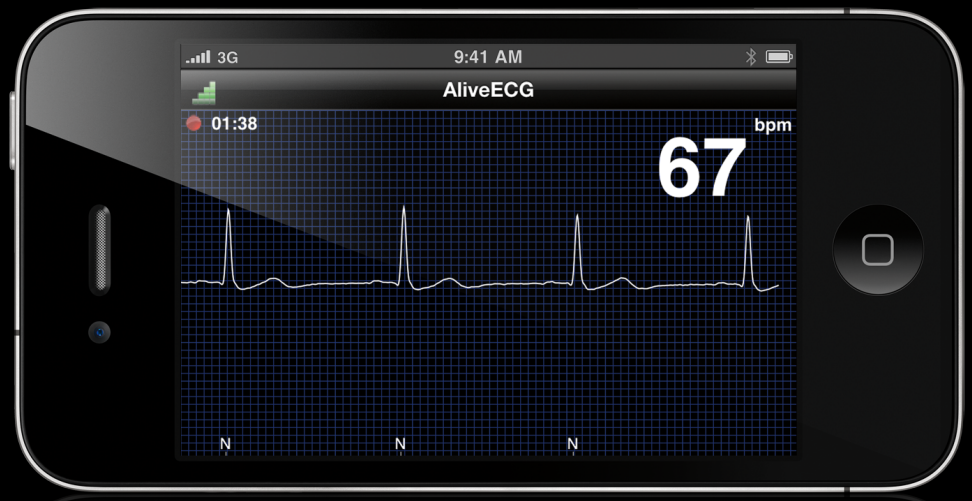
Source: Offline and Falling Beyond: Barriers to Internet Adoption, McKinsey & Co., 2014

Other Wearable Devices/Sensors





mPCDs in Healthcare



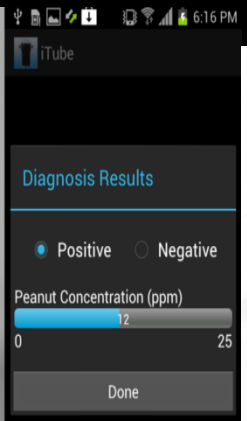
Courtesy: AliveCor

Cervical Cancer Detection

Courtesy: mobileOCT

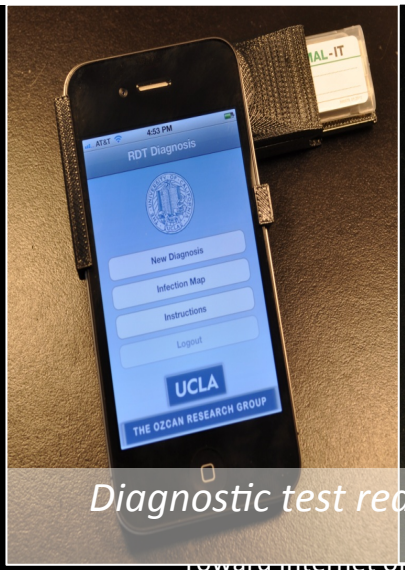
From Ozcan's Research Lab (UCLA)

E. coli sensor

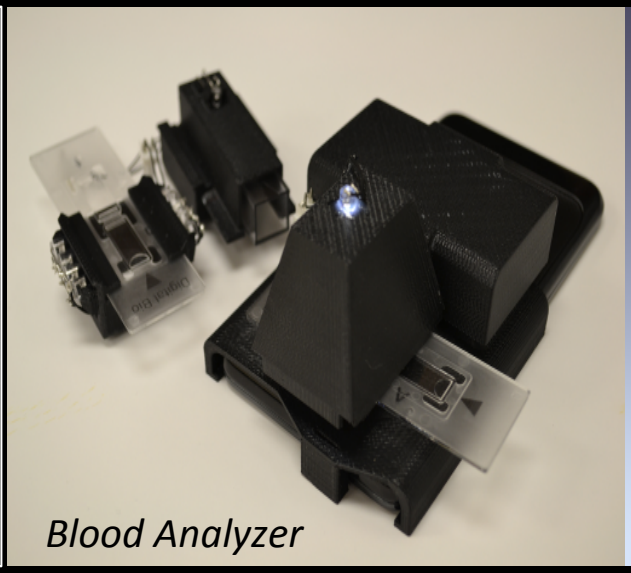


Allergen detector

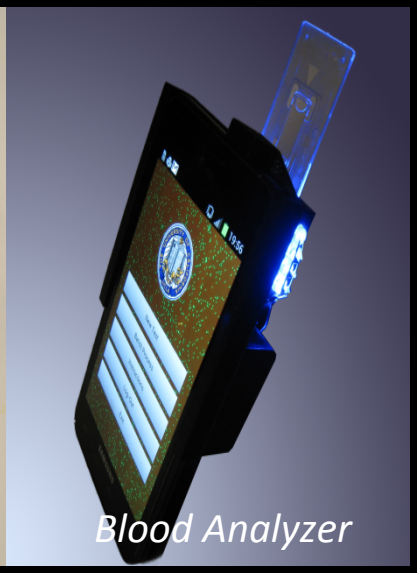
Google Glass based Diagnostics



Diagnostic test reader (HIV, malaria, etc.)



Blood Analyzer



Blood Analyzer

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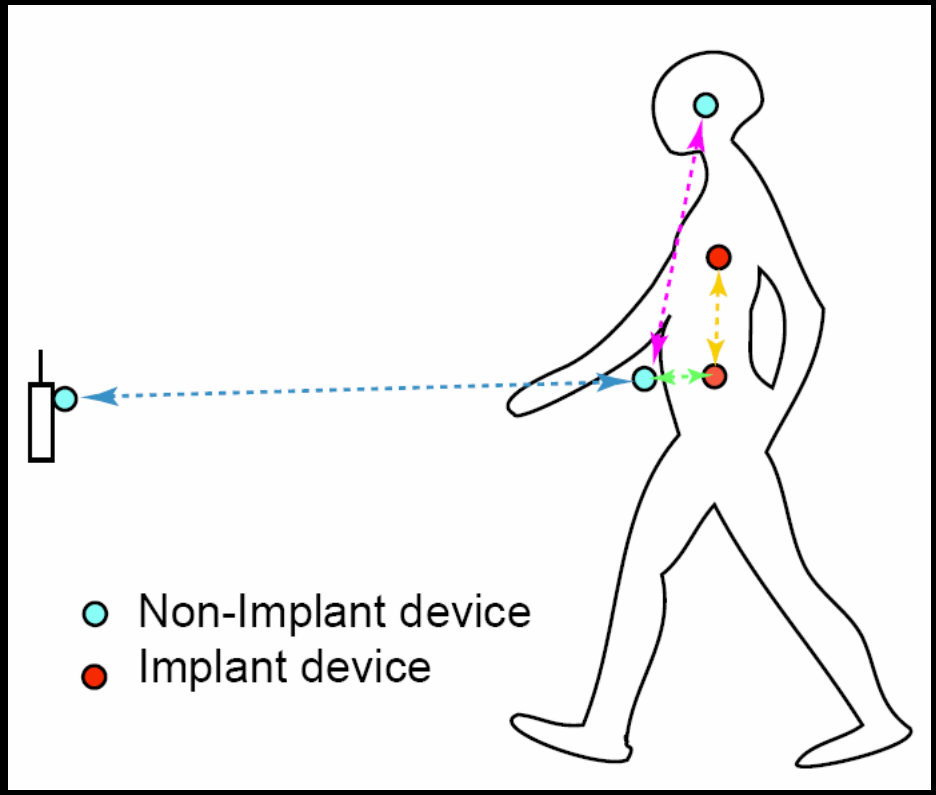
Toward Body Area Networks (BAN)

A Body Area Network (BAN) is a radio communication standard for short range, low power and highly reliable wireless communication for use in close proximity to, or inside, a human body



Main Features

- 2 types of nodes: Implantable, Wearable/adjacent to the body
- A variety of cutting edge medical applications & some personal entertainment services
- Data rates: up to 10Mbps
- Operating at frequency bands approved by regulatory authorities

Courtesy: Kamran Sayrafian

Health/Medical Applications

Medical/physiological monitoring
- Electroencephalogram EEG
- Electrocardiogram ECG
- Electromyography EMG
- Temperature
- Respiration monitor
- Heart rate monitor
- Pulse oximeter SpO2
- Blood pressure monitor
- pH monitor

Disability assistance
- Muscle tension monitor
- Muscle tension stimulation
- Weighing scale
- Fall detection
- Hearing aid

Implant
- Glucose sensor
- Brain liquid pressure sensor
- Endoscope capsule
- Drug delivery capsule
- Deep brain stimulator
- Brain-computer interface
- Pacemaker
- Insulin pump
- Hearing aid
- Retina implants

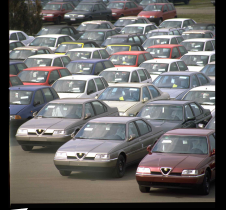
Human performance management
- Aiding professional and amateur sport training
- Assessing emergency service personnel performance
- Assessing soldier fatigue and battle readiness

Courtesy: Kamran Sayrafian

Technology Trends

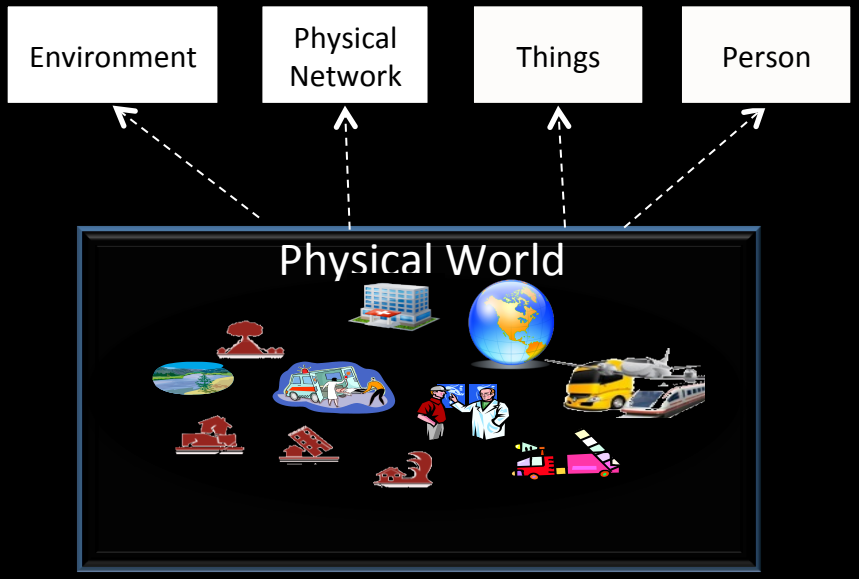
1. Ubiquitous mPCDs and other wearable devices
2. Devices connected through Internet

Internet of Things



Connecting Devices

Courtesy: Ramesh Jain, UCI



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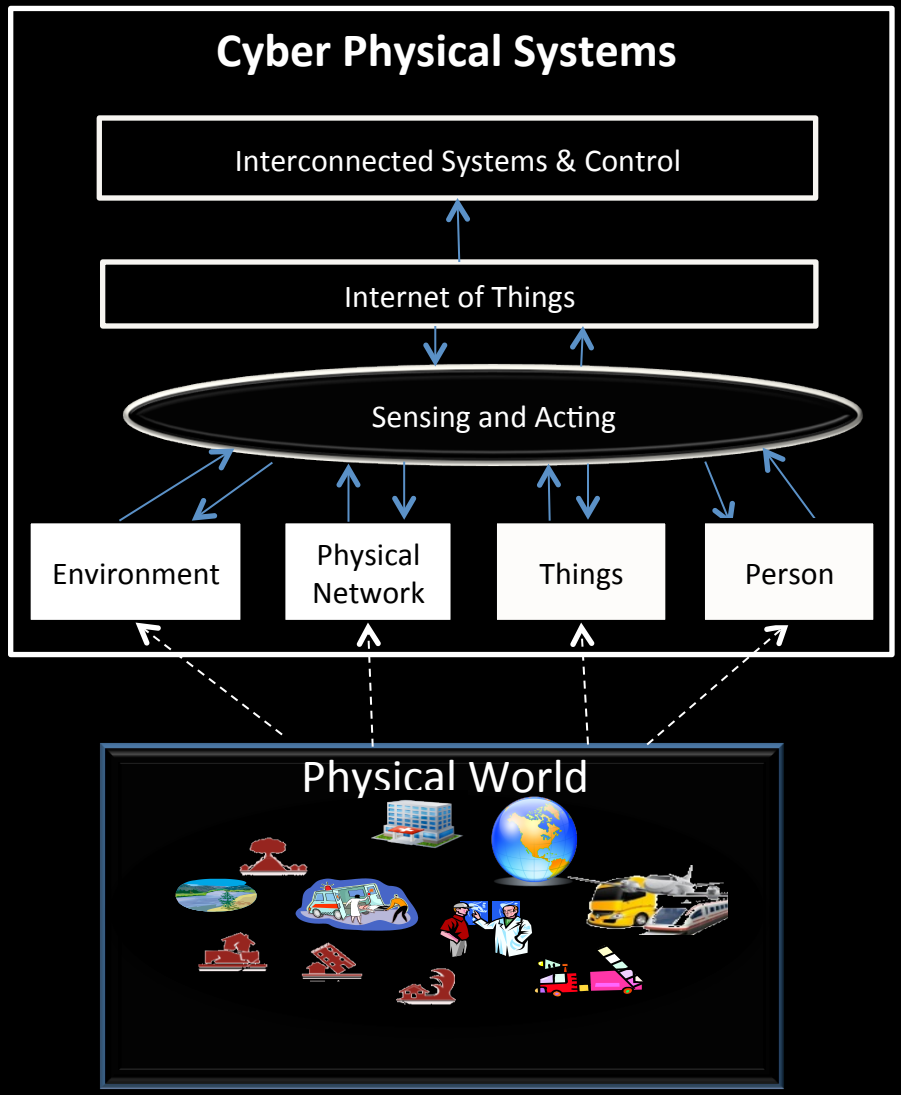

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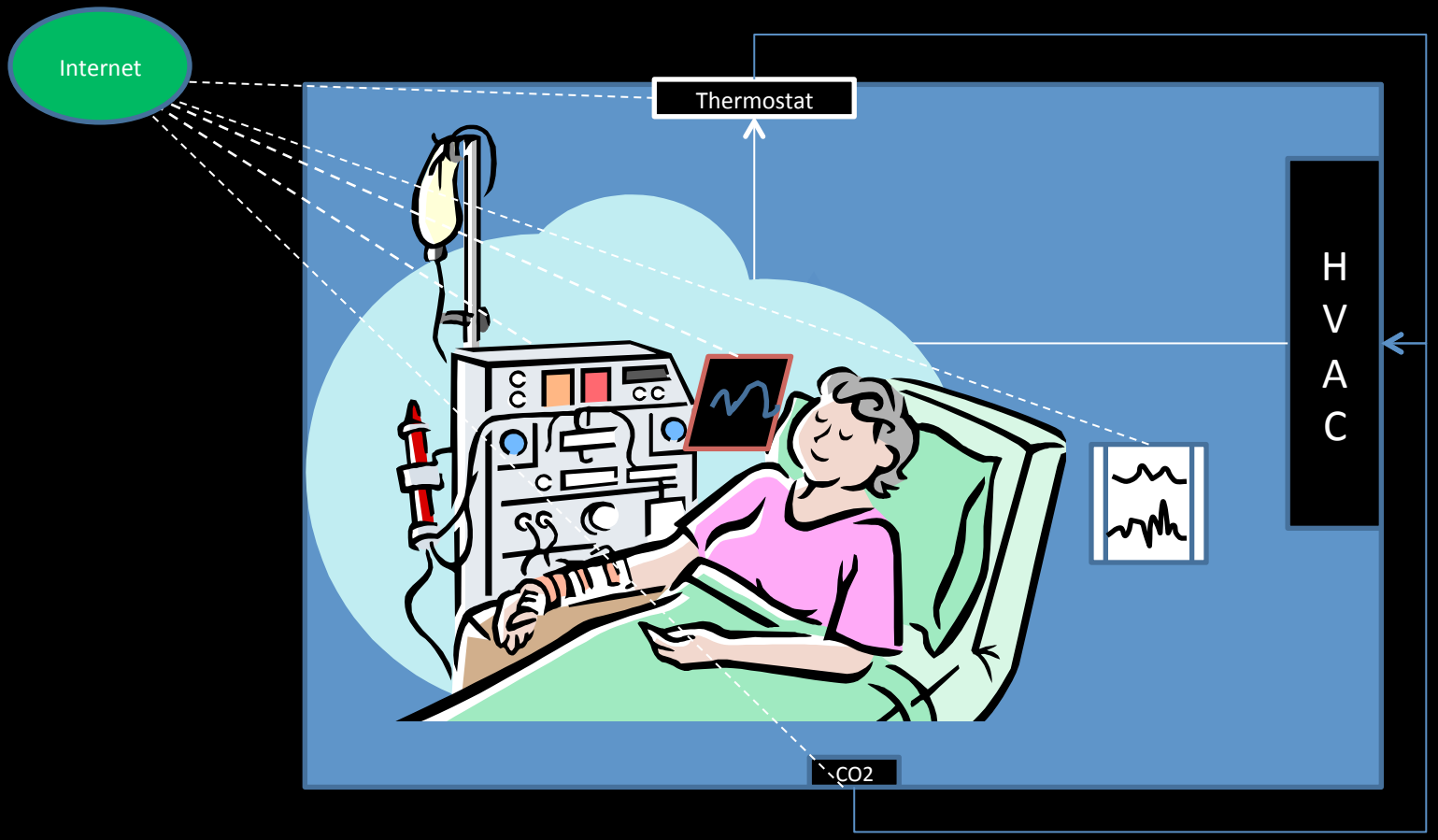
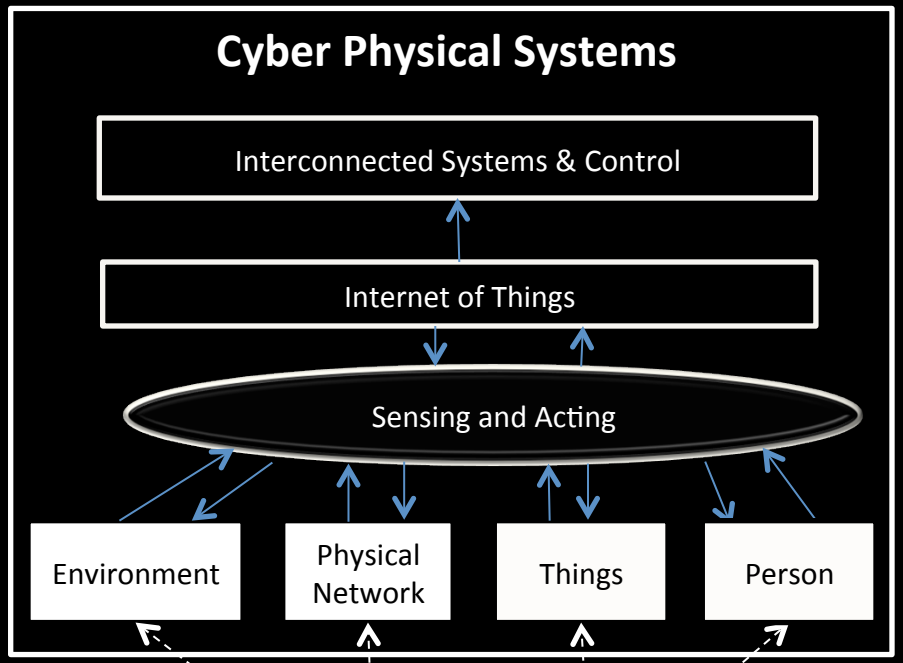
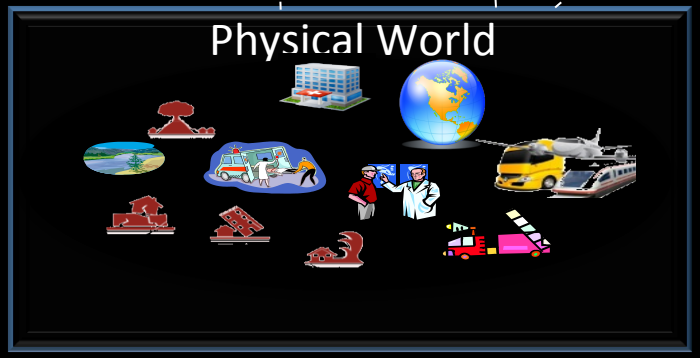
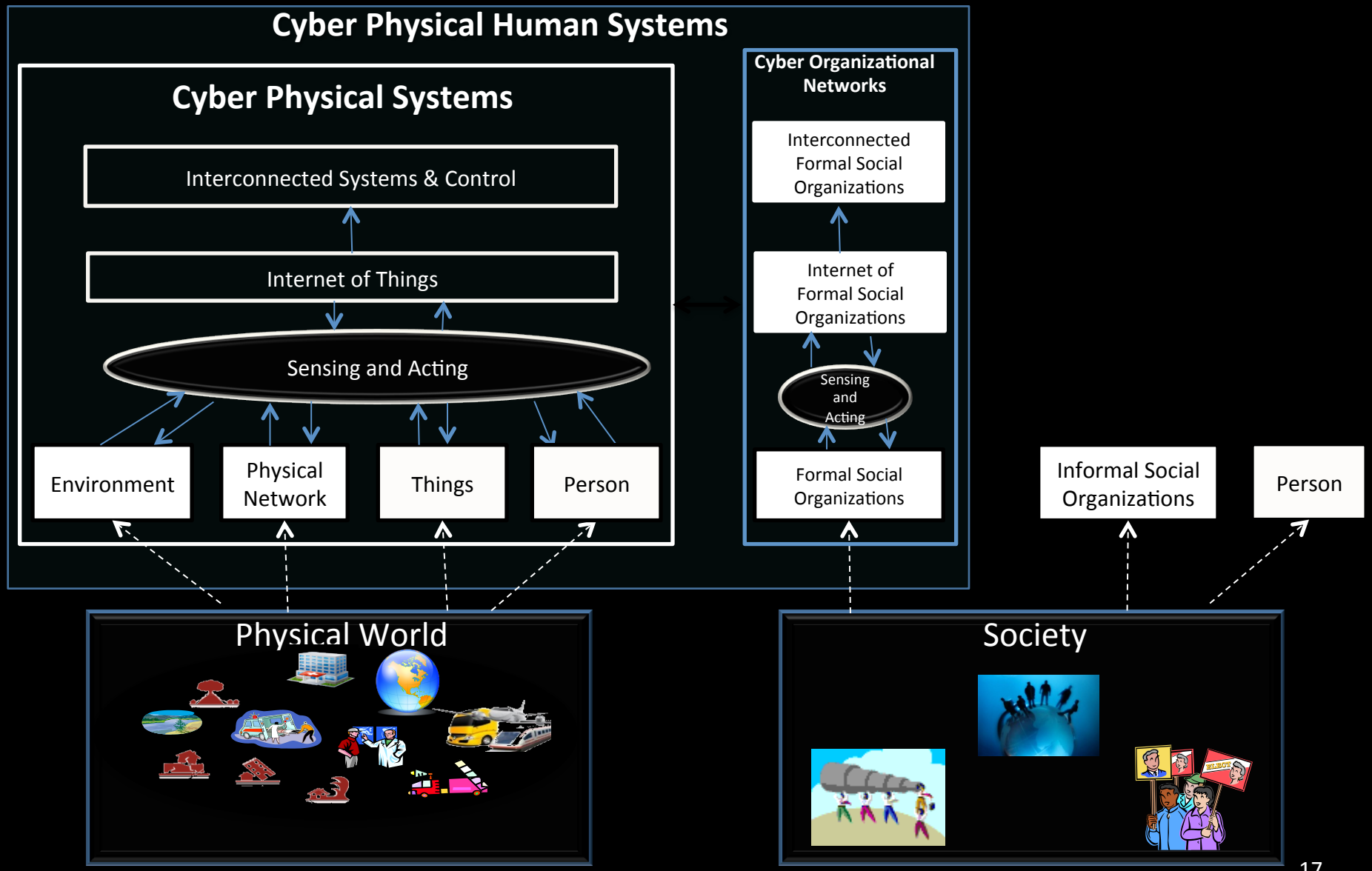
CPS Example







Toward Internet of Everything, NIST



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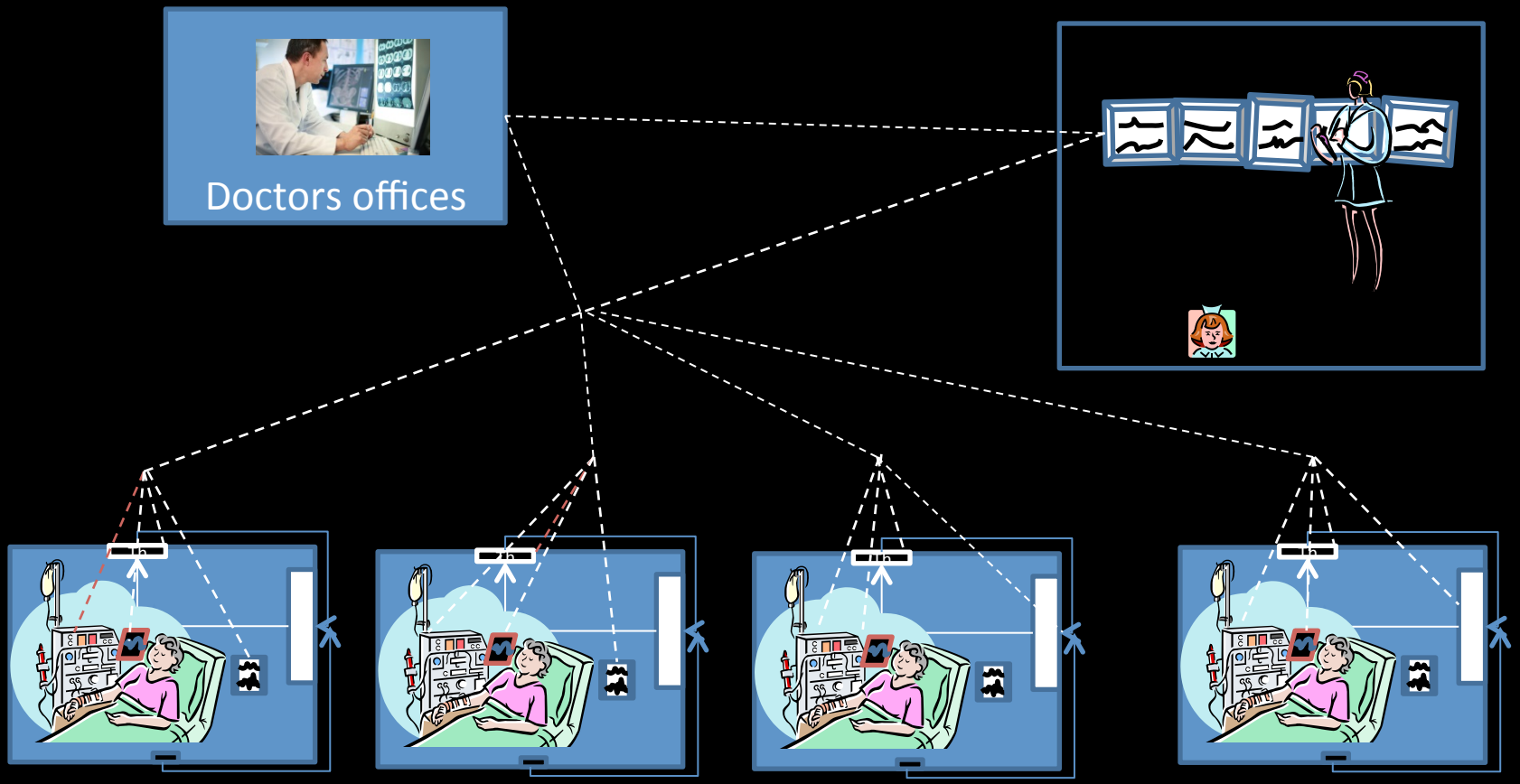
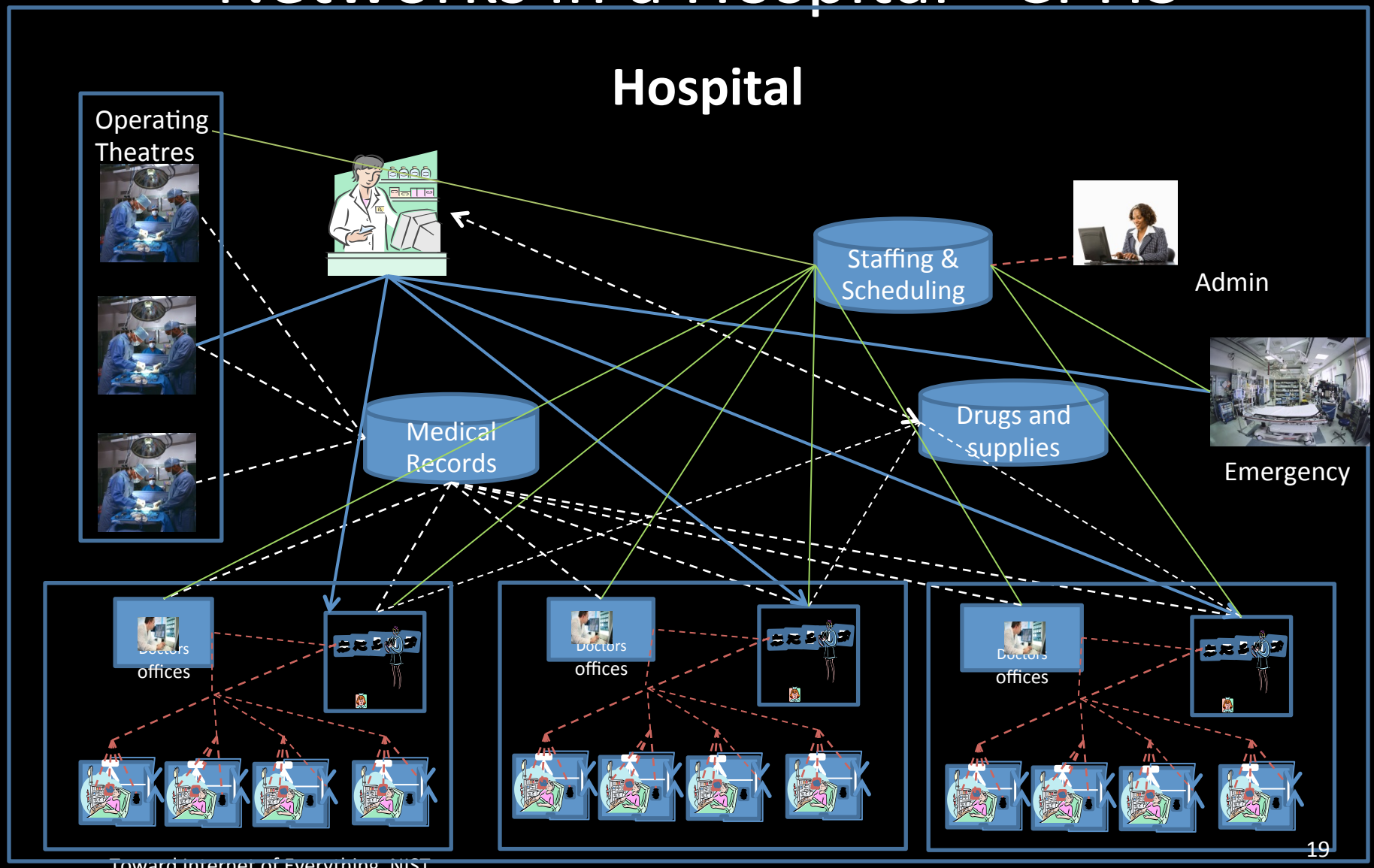
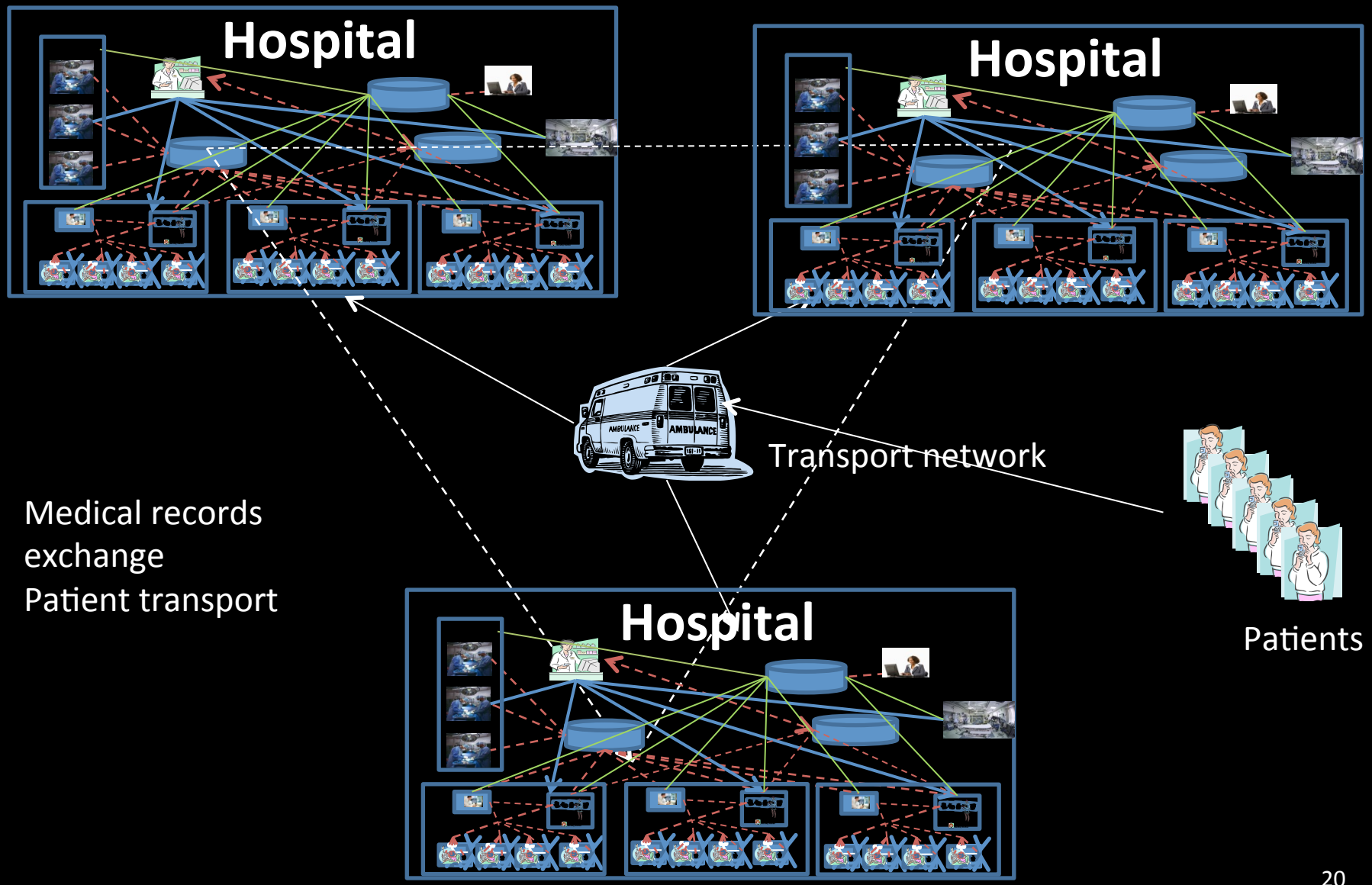
CPHS Example: Monitoring-Multiple Patients in a Ward



Information, Transport & Operations Networks in a Hospital - CPHS



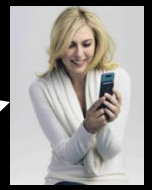
Inter-connected CPHS



Technology Trends

1. Ubiquitous mPCDs and other wearable devices
2. Devices connected through Internet
3. Emergence of social networks

Social Networks



Connecting People

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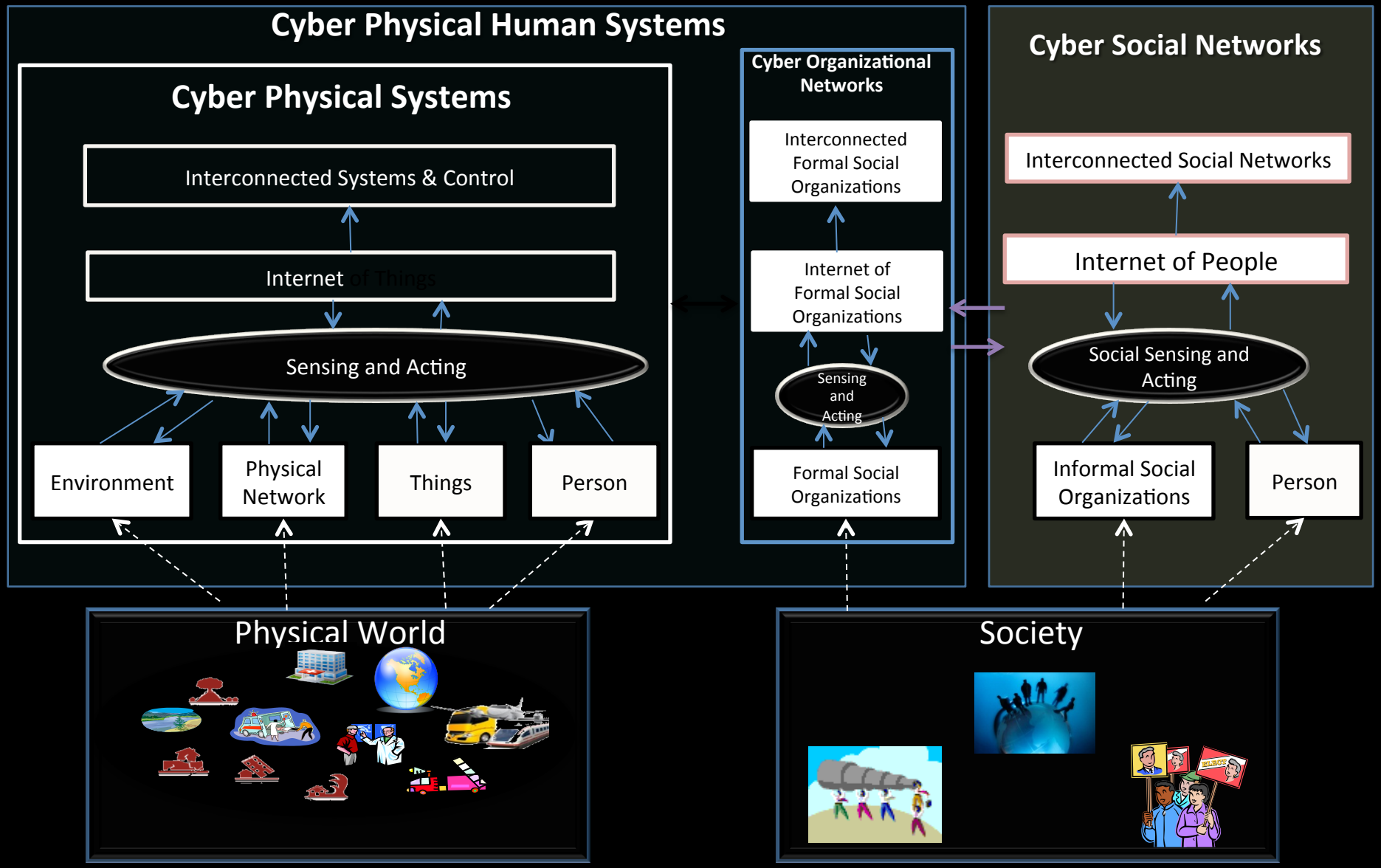
Courtesy: Ramesh Jain, UCI



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Sub, Ahmed, Sriram

Smart Networked Systems and Societies

Interconnected Cyber Physical and Social Networks

Cyber Physical Human Systems

Cyber Physical Systems

- Interconnected Systems & Control
- Internet of Things
- Sensing and Acting
- Environment
- Physical Network
- Things
- Person

Cyber Organizational Networks

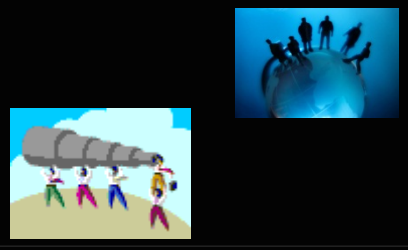
- Interconnected Formal Social Organizations
- Internet of Formal Social Organizations
- Sensing and Acting
- Formal Social Organizations

Cyber Social Networks

- Interconnected Social Networks
- Internet of People
- Social Sensing and Acting
- Informal Social Organizations
- Person

Physical World

Society



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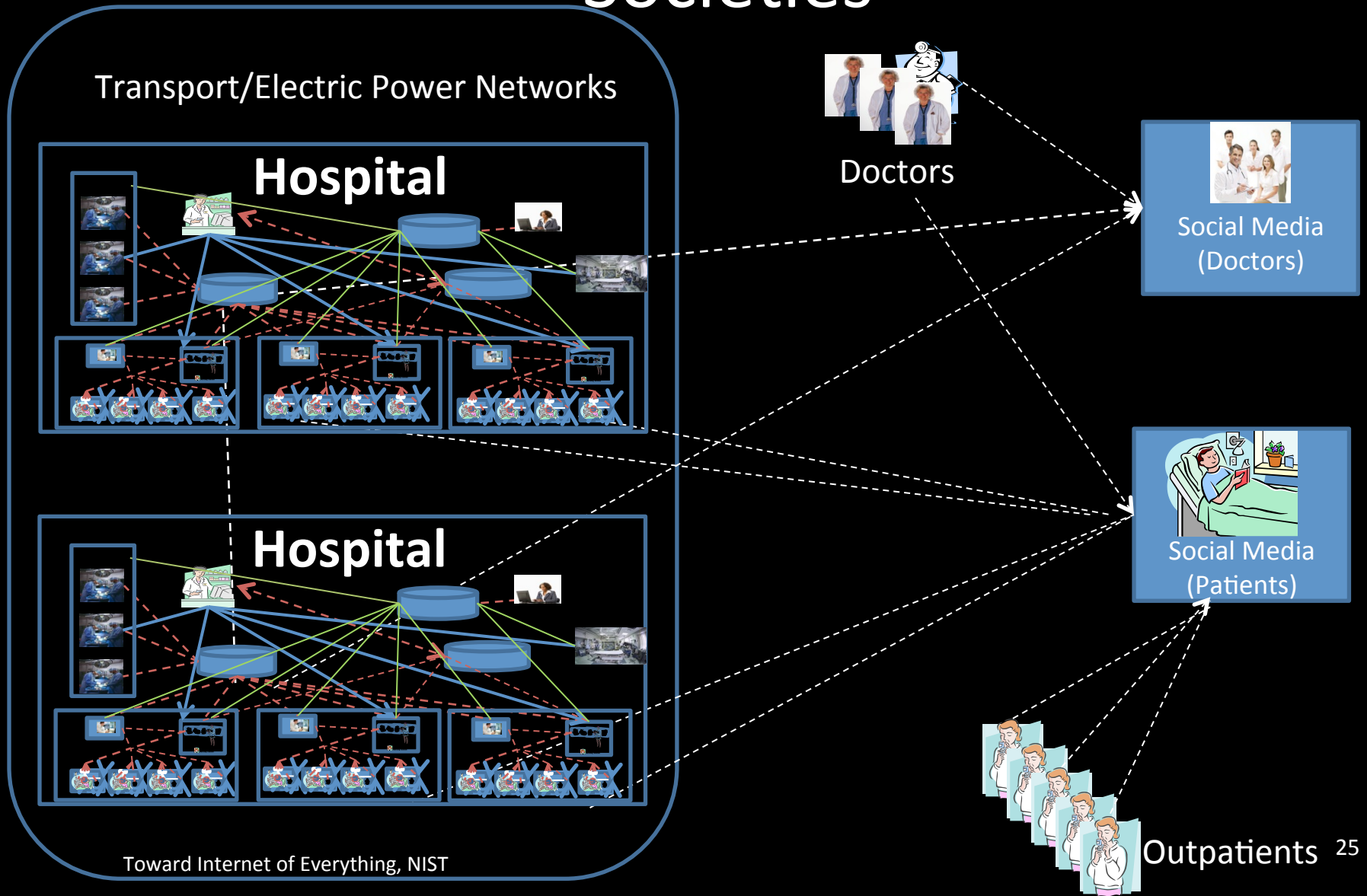
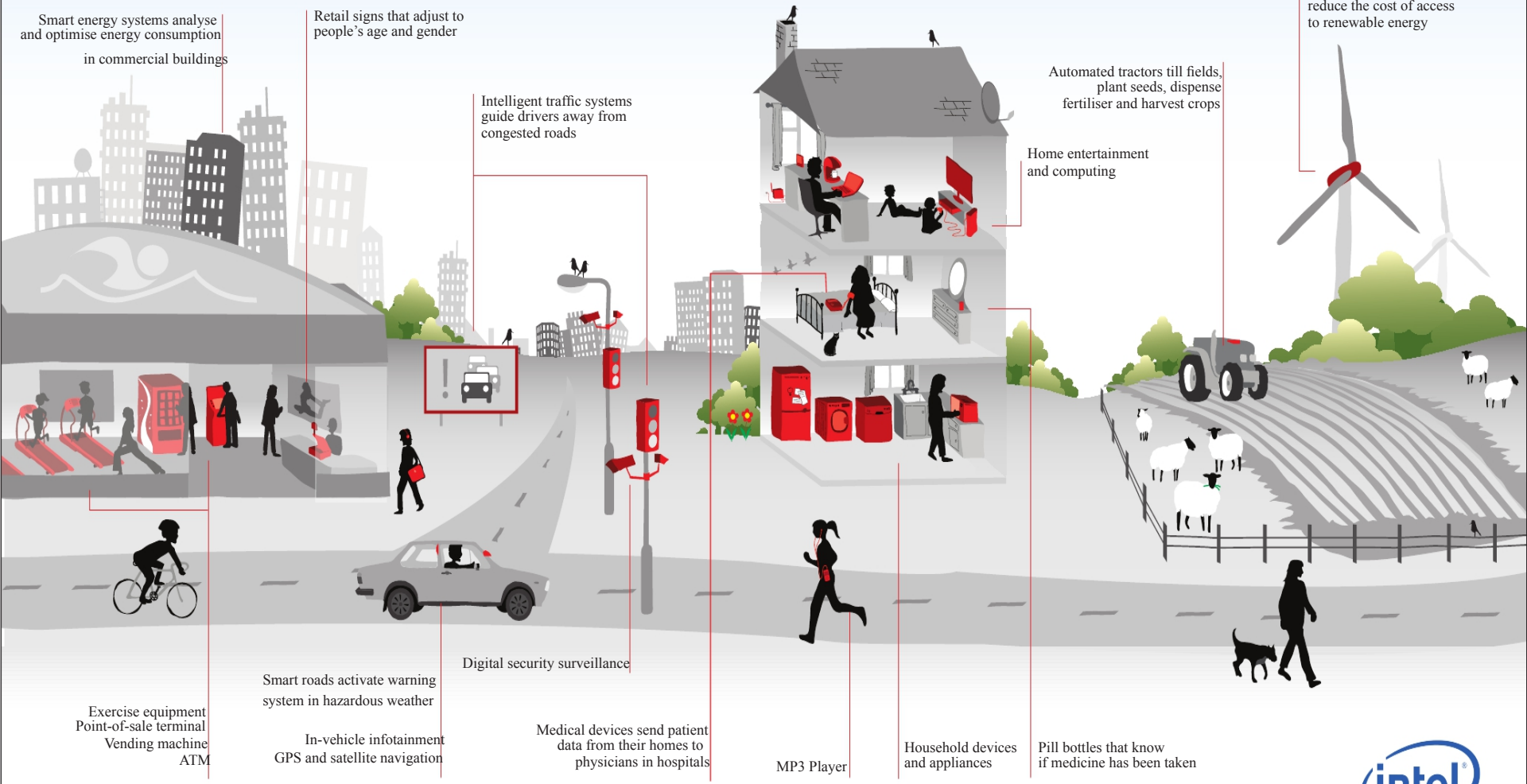
Smart networked Systems and Societies



It’s a Smart World

Invisible yet ubiquitous, small but mighty, unnoticed but life changing. Forty years ago the microprocessor was born, beginning the quiet but profound process which has radically reshaped our lives. Today, thanks to the microprocessor, we live in a smart world, can do smart things and make smart choices. We don’t see them, but these tiny embedded computers shape our world to a remarkable degree. From the cars we drive and tractors that till the fields, to the fresh food delivered to our shops, billboards that advertise and machines that help us stay fit – they’re the invisible brains that power our daily being. Long live the smart life.



IT CHALLENGES

IT R&D Challenges

1. Privacy and Security/Assurance

Privacy and Security

- Privacy
  - Labeling
  - Provenance
  - Context
  - Policy
  - Cryptography
  - Analytics
- Device Security
  - Authentication
  - Device Loss
  - Others
- Wireless Security
  - Eavesdropping
  - DoS, Phishing, Etc
- Data Security
  - Encryption
  - Access Rights
  - Audit Trails

Privacy in Android App

Analysis of Horoscope for Android

Horoscope

Horoscope.fr
Category: Lifestyle
Price: Free

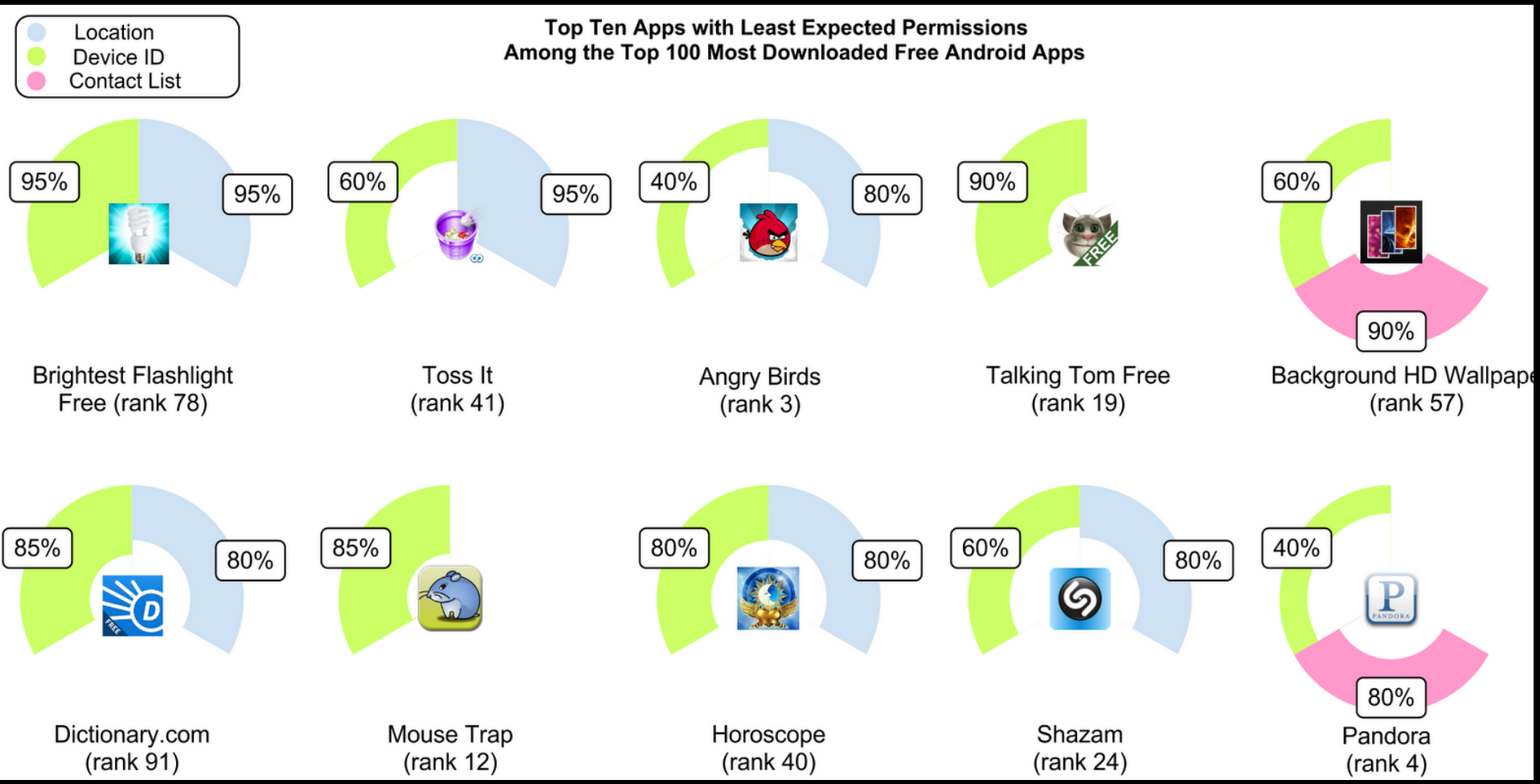
Description
Check your complete horoscopes for today, tomorrow and much more ! Horoscope : The official Horoscope from horoscope.fr now available on your Android phone ! 100% FREE, 100% PRO !

Resource	Used by	Description
Device ID	Used for indexing users	
Location	Flurry	App analytics
Other 3rd-party libraries app uses	Facebook Twitter	

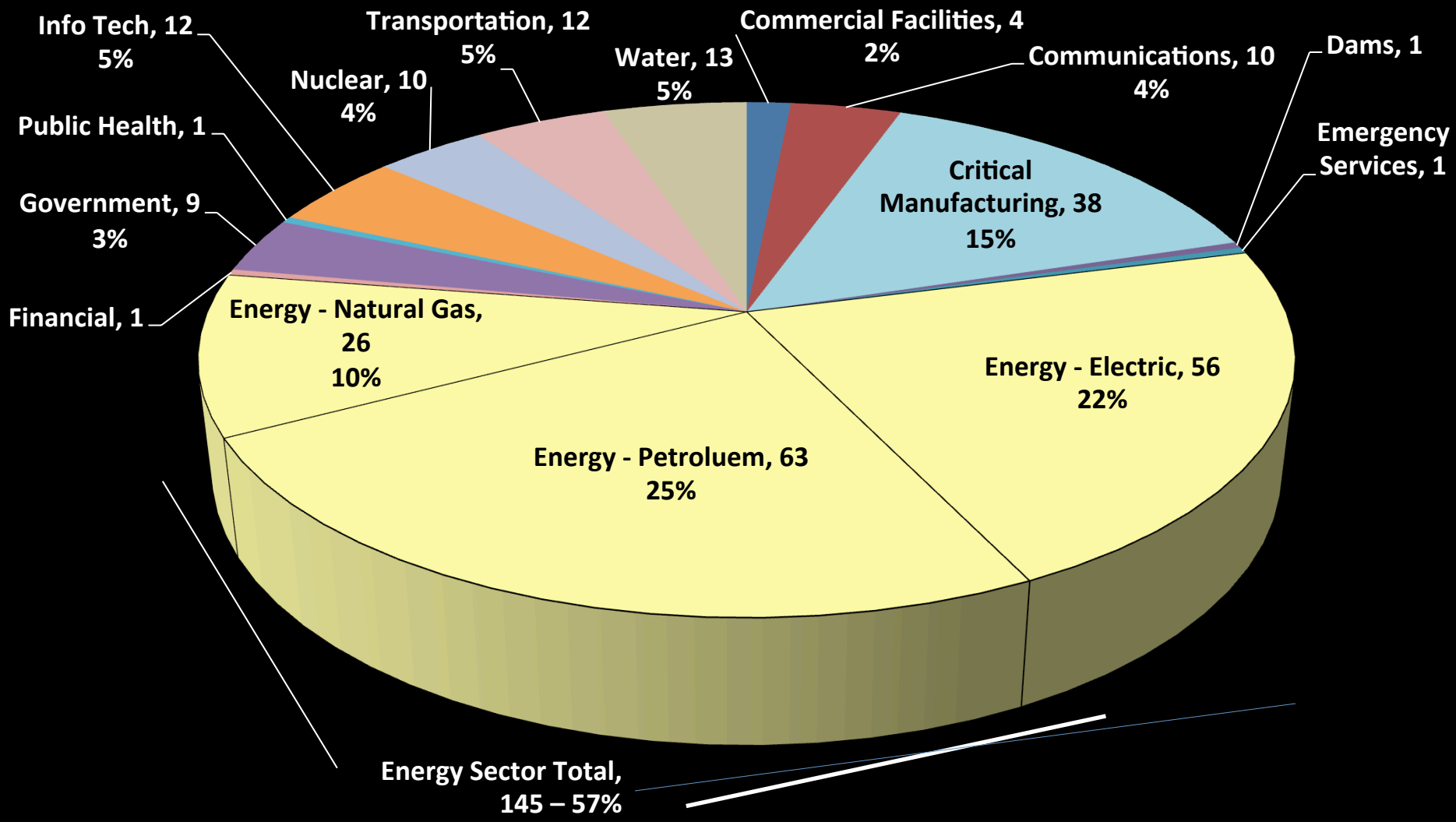
Privacy Analysis	Description
	· 80% of people were surprised Horoscope uses your unique Device ID · 80% of people were surprised Horoscope uses your location You can read more about our research on app privacy here.

Courtesy: Jason Hong, CMU

Privacy In Apps



Security: FY-2013 Incidents Reported by Sector



Courtersy: Dept. Homeland Security

Challenges For Privacy

From NIST Workshop (April 2014)

- Address getting consent in IoT, wearable devices, image capture, etc..
- Develop tools for measuring effectiveness of privacy practices
- Put in place adequate risk management procedures
- Generate use cases to guide system design

What about Privacy and Innovation?

http://www.nist.gov/cyberframework/upload/privacy-workshop-summary-052114.pdf

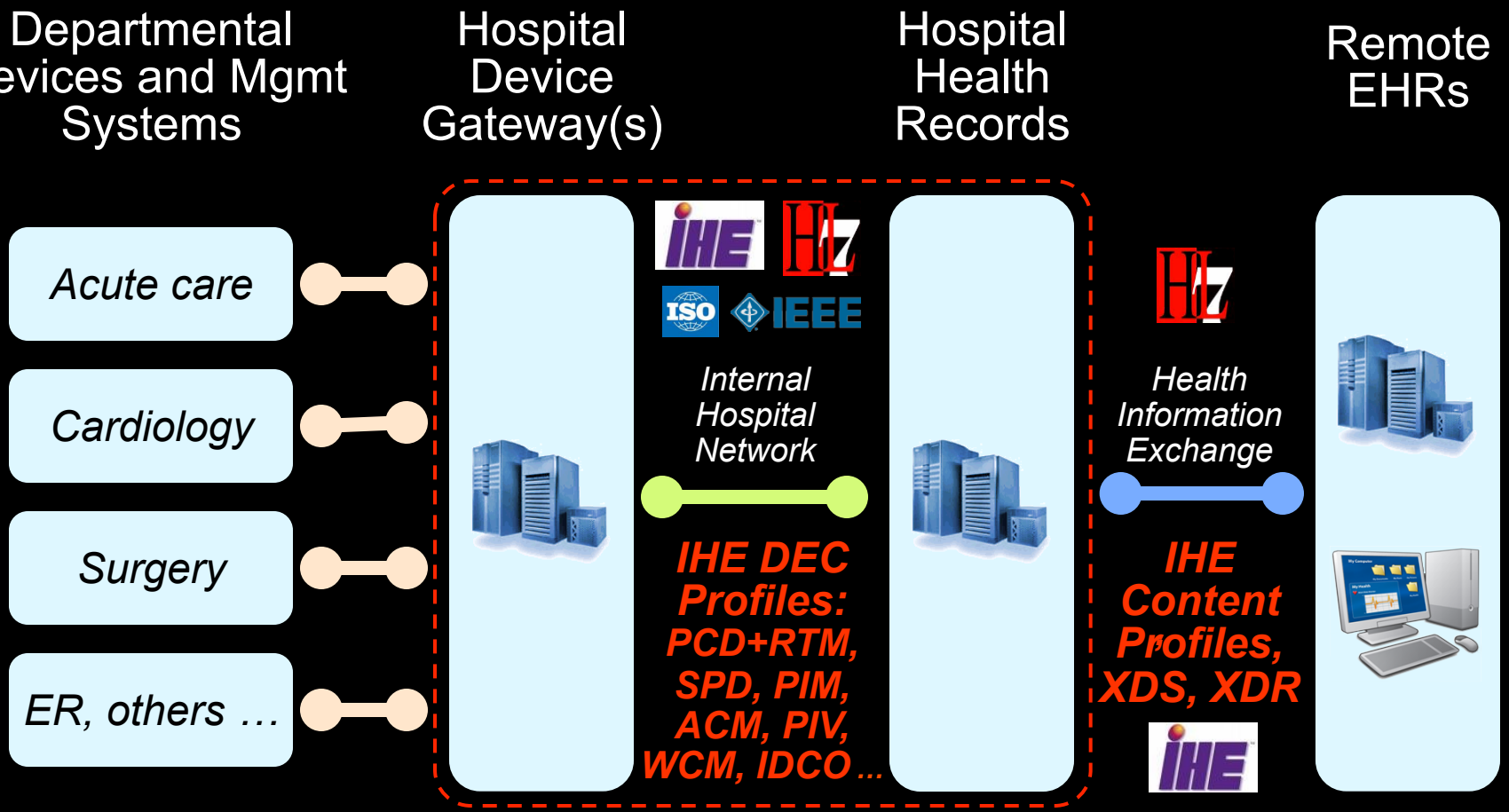
Challenges For Security

- Accelerate security standards development for mPCDs
- Develop protocols for information security
- Conduct research on novel encryption algorithms
- Take adequate measures to block spoofing of SNSS
  - GPS
  - Social networks
- Build better security into both hardware and software
  - Designed-in Security
  - Firmware security
- Develop best practices for cybersecurity
- Develop technologies and measurements for biometrics-based security

IT R&D Challenges

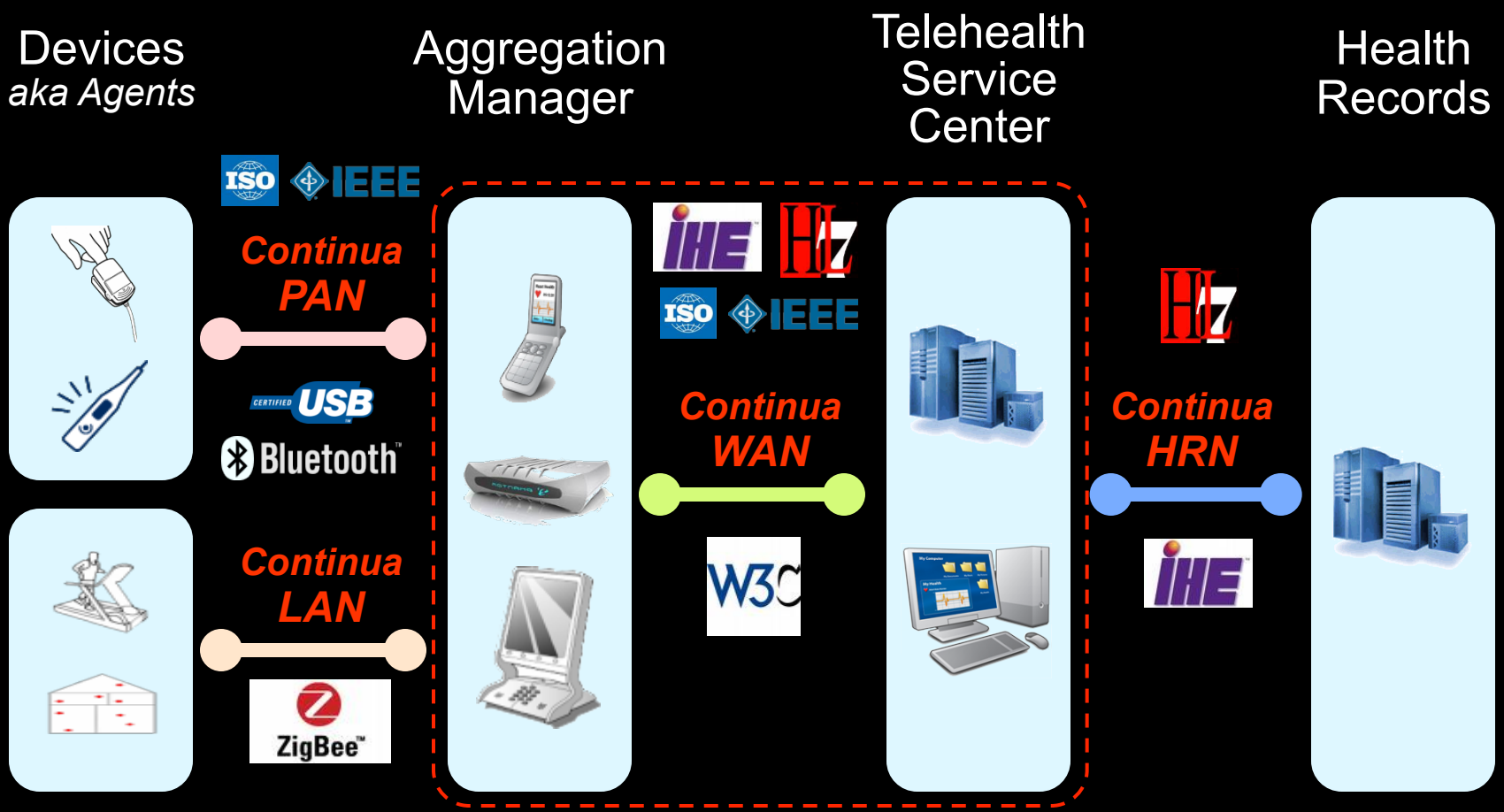
1. Privacy and Security/Assurance
2. Interoperability

Clinical Device Connectivity



Note: *IHE Profiles shown above are being demonstrated at HIMSS11 as trial implementations;* ***IHE DEC PCD-01*** *Technical Framework "Final Text" will be available in Q2 2011.*

Personal Health Device Connectivity



Note: *Continua Version 1.5 Guidelines available today; Version 2011 available later this year. The Continua WAN interface uses the **IHE DEC PCD-01** transaction over Web Services.*

Challenge

Need to achieve both syntax and semantic interoperability

Fractured CPS Standards Landscape

The first remotely operated domestic machine — a toaster — was connected to the Internet less than a quarter-century ago, in 1990. The Internet of Things (IoT) doubled in size a year later with the addition of a coffee pot. Eventually, the Internet Engineering Task Force Network Working Group assigned the coffee pot its own specific standard, HTCPCP 1.0, the Hyper Text Coffee Pot Control Protocol, RFC 2324.

We're moving to a world in which everything is connected. Whoever dictates in the most real sense how it [the IoT] connects will be at a competitive advantage in terms of the exponential growth of the market, and anyone who fails to align themselves with the winning standard is going to be left out in the cold. So, it's no surprise that certain vendors would like to hijack the market by establishing new sets of standards that work to their advantage.

- Jeffrey Kaplan, THINGStragies, 2014

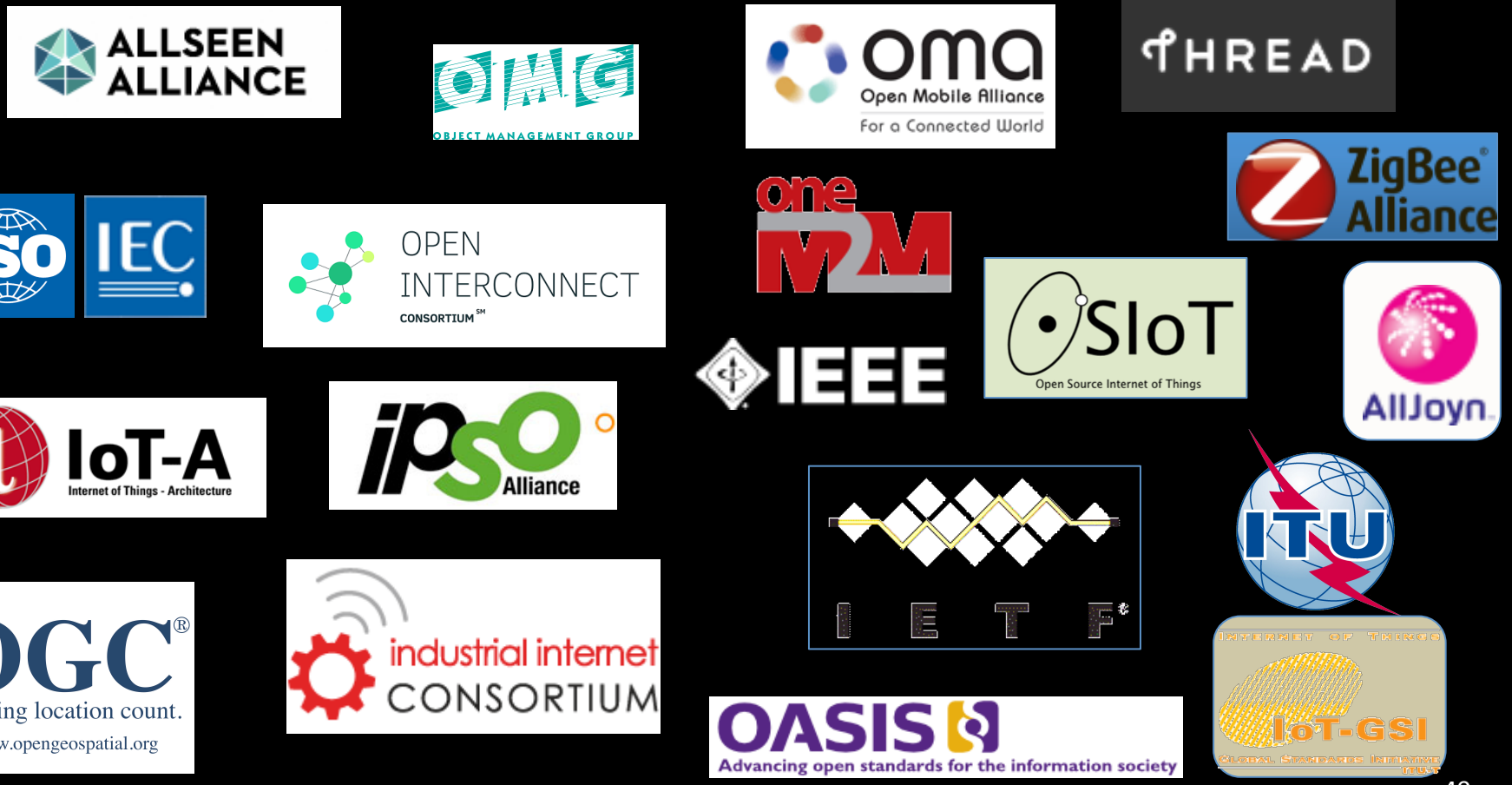
The successful adoption of standards that are device-, OS-, and network-agnostic would put the Internet of Things on hyperdrive.

- Peter Lewis, Sept. 2014

Courtesy: Dr. Chris Greer

Fractured CPS Standards Landscape

Having all these different standards efforts practically ensures one thing: There's no way all of these devices will actually be able to all talk to each other until all this gets settled with either victory or a truce. Ina Fried, July 2014



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Courtesy: Dr. Chris Greer

IT R&D Challenges

1. Privacy and Security/Assurance
2. Interoperability
3. Knowledge Representation (Ontologies)

Modeling the World

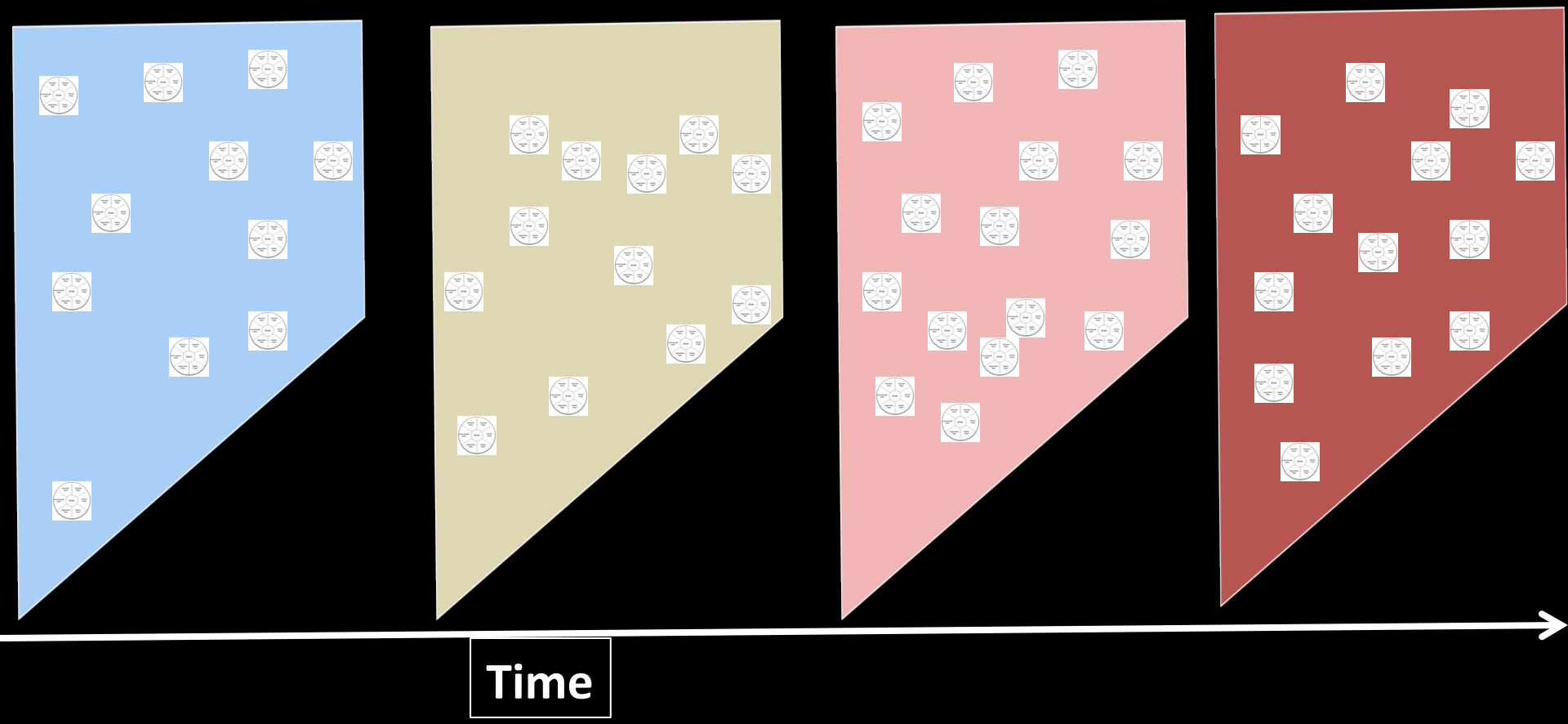
- Data
- Objects
- Relationships and Events

Events are ‘Connectors’
Events create ‘Context’

People
Things
Places
Time
Experiences
Events

Toward Internet of Everything, NIST

Events are currently just a time-indexed database.



facebook

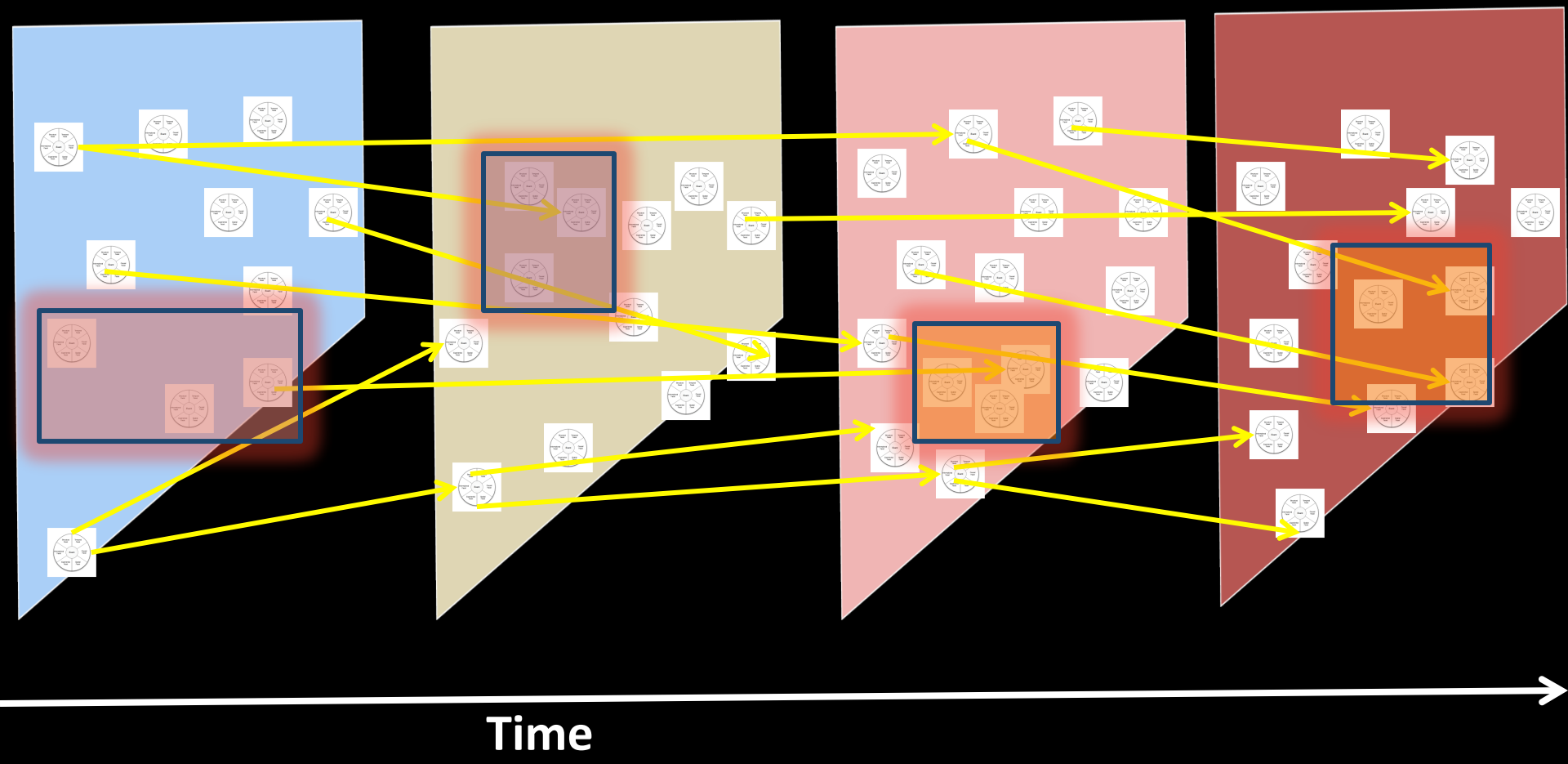
twitter

YouTube™

AP | Getty Images

EventWeb: Compositing and Linking

Atomic and Composite Events



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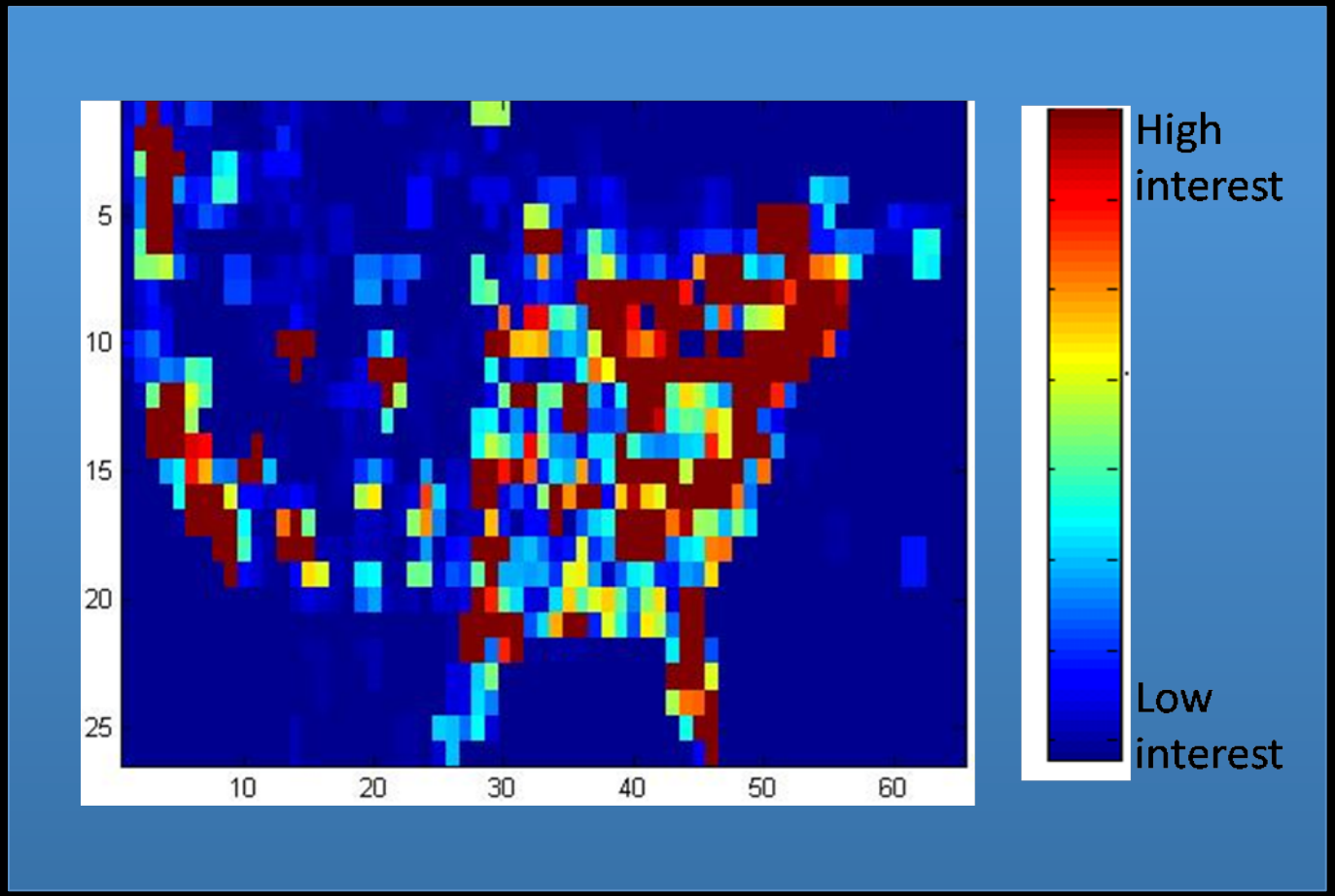
Courtesy: Ramesh Jain, UCI

Emage: Event Image

- **Divide space (world) into small Pixels of appropriate size.**
- **Assume that each event is a particle of a specific type. Create a Social Image for specific type of events.**
- **A time-ordered sequence of these emages will be similar to a video representing spatio-temporal changes in events of that type.**

Slides courtesy of Ramesh Jain

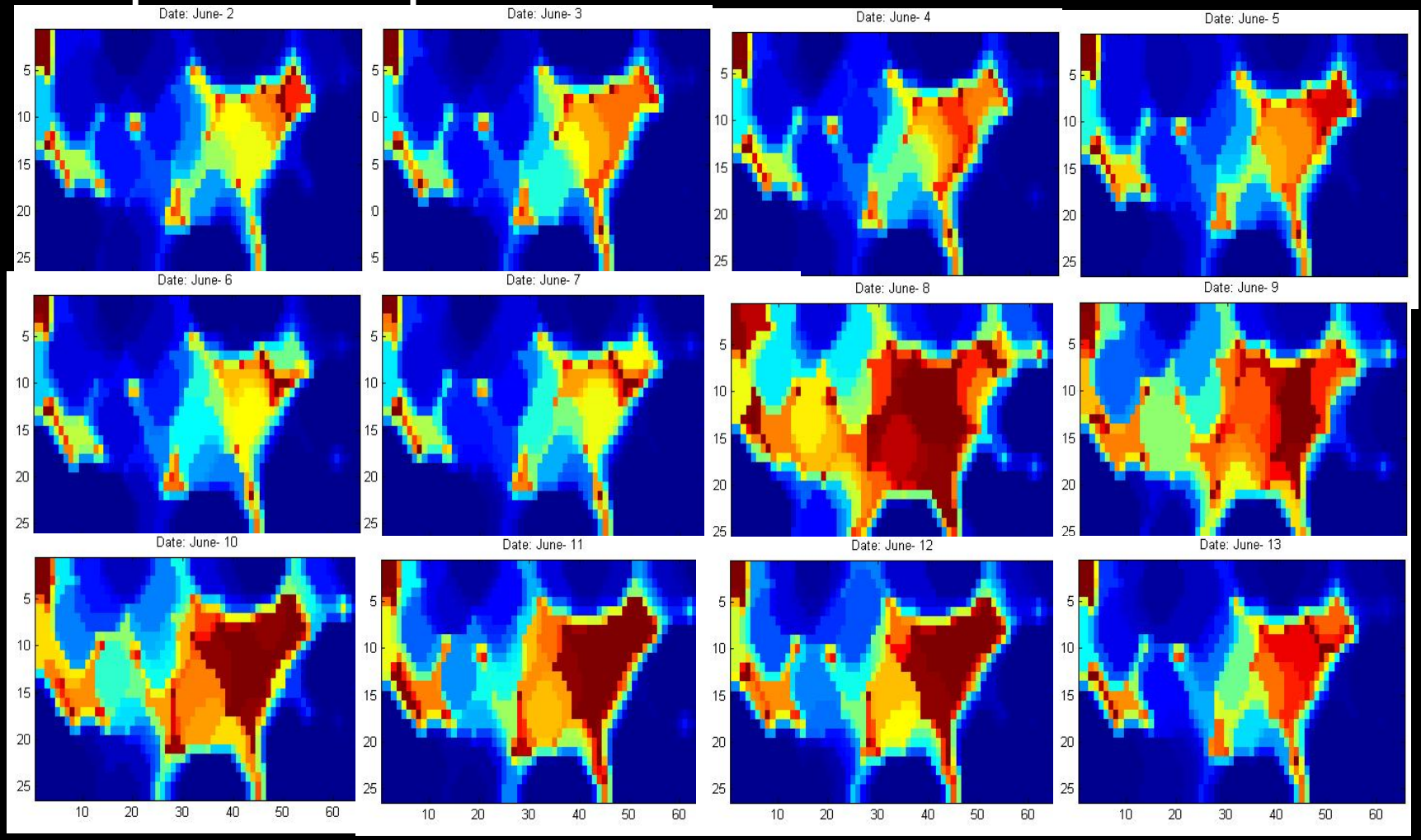
Example Social Image- (iphone)



Slides courtesy of Ramesh Jain

iPhone

- Spatio temporal variation: Event detection



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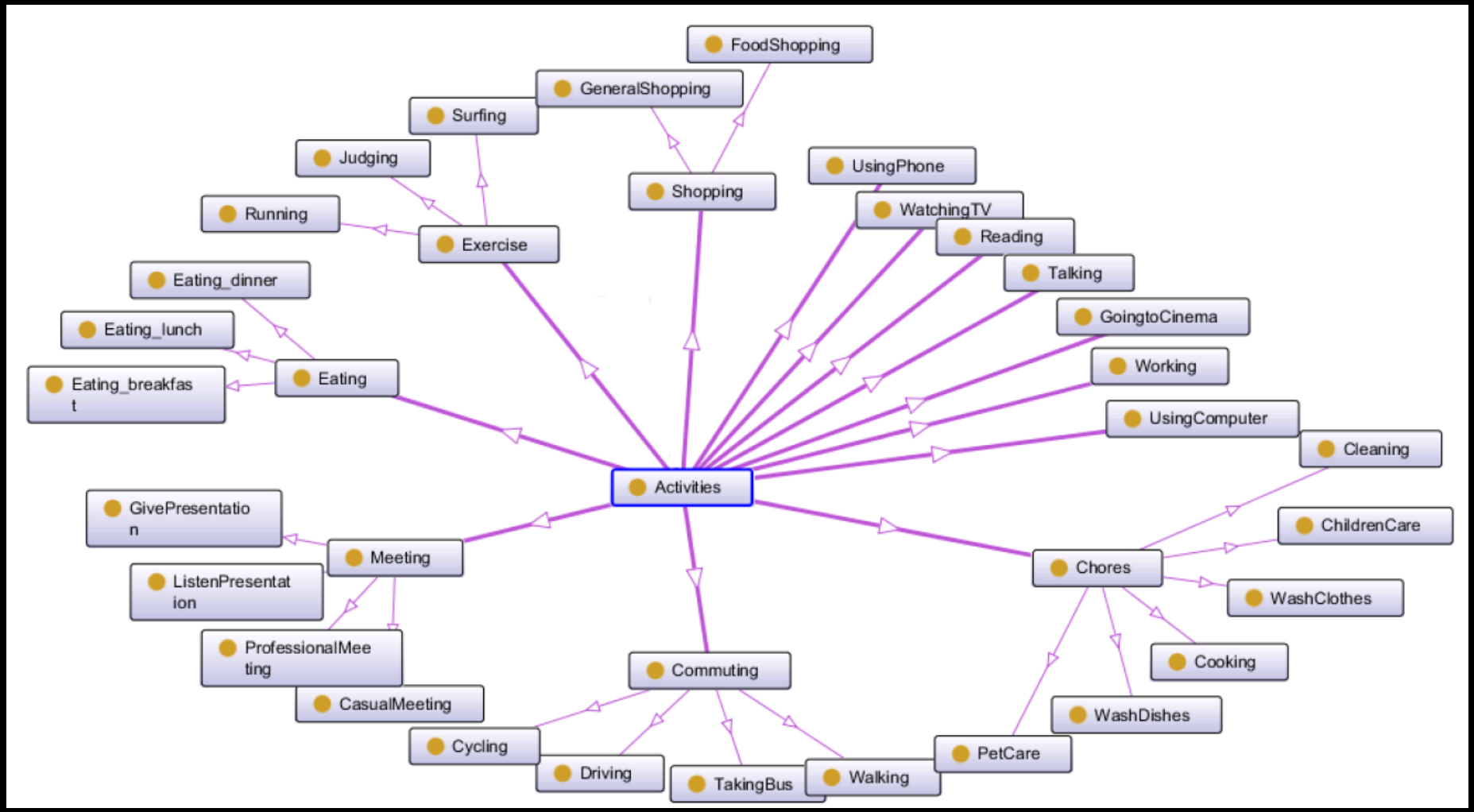
Slides courtesy of Ramesh Jain

Life Event Ontology



Toward Internet of Everything, NIST

Courtesy: Ramesh Jain, UCI

Challenges

- Research into multimodal ontology frameworks (micro-blogs, micro-events, e-images, etc.)
- Develop event ontologies for targeted domains (building from core ontologies)
- Develop testing methods for evaluating ontologies
- Implement prototype demonstrations

IT R&D Challenges

1. Privacy and Security/Assurance
2. Interoperability
3. Knowledge Representation (Ontologies)
4. Knowledge/Information/Data Analytics

Decision Analytics

Courtesy: Ramesh Jain, UCI

Challenges For Multilevel Decision Making

- Levels of Decision Making
  - Executive Level
  - Middle Level
  - Control Levels
- Decision Making Tools and Techniques
  - Mechanism Design
  - Game Theory
  - Advanced Control Algorithms
- Mapping Between Levels

Geo-Social Data Collection (Japan Tsunami)

Category	Sub-Categeotry	Title	# Records	Byte(s)	Start	Last	Update Freq.
Social	Map	Hospitals	165,425	25,778,876	2010/3/29 0:00	2010/3/29 0:00	yearly
Social	Map	Public Facilities	44,793	6,221,028	2010/3/29 0:00	2010/3/29 0:00	yearly
Social	Map	Railways	20,594	25,746,980	unknown	2010/3/29 0:00	yearly
Social	Map	Landmarks	1,418,247	317,439,712	unknown	2010/3/29 0:00	monthly
Social	News	JapanNews	1,293,303	25,093,656,172	2010/8/17 15:00	2011/12/12 22:42	minutely
Social	SNS	Twitter	227,296,594	31,822,390,980	2010/6/13:25	2010/11/10 11:45	minutely
Natural	Disaster	Earthquake	18,189	1,524,396	2011/1/18:01	2011/12/12 5:43	minutely
Natural	Disaster	Landslide	758,086	424,894,372	2010/3/29 0:00	2010/3/29 0:00	monthly
Natural	Disaster	Typhoon	200	26,908	2011/9/7 12:00	2011/10/12 18:00	minutely
Natural	Radiation	Radiation	302,029	28,044,960	2011/3/11 0:00	2011/12/10 8:00	daily
Natural	Weather	Precipiation	1,644,754	168,132,636	2011/9/7 12:00	2011/12/12 9:00	minutely
Natural	Weather	Temperature	1,138,361	120,504,640	2011/9/7 11:00	2011/12/12 9:00	minutely
Natural	Weather	Wind	1,181,848	151,482,592	2011/9/7 11:00	2011/12/12 9:00	minutely

Courtesy: R. Lee, NICT


Messages during Japanese Tsunami

7Vs: Volume, Velocity, Variety, Veracity, Value, Viewpoint, Visualization

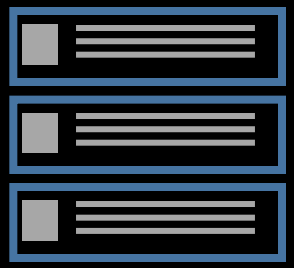
Big Data-Bases
Massive Information Sources
Large Knowledge Networks

Challenges

- Develop and test algorithms for categorization, pattern recognition, statistical learning, and visualization
- Develop and test efficient techniques for analyzing multimodal information
- Develop techniques for discovering personality traits from social media
- Propose standard operators for various information processing tasks
  - Access, Aggregate, Assimilate, Filter
- Build infrastructure for large knowledge networks

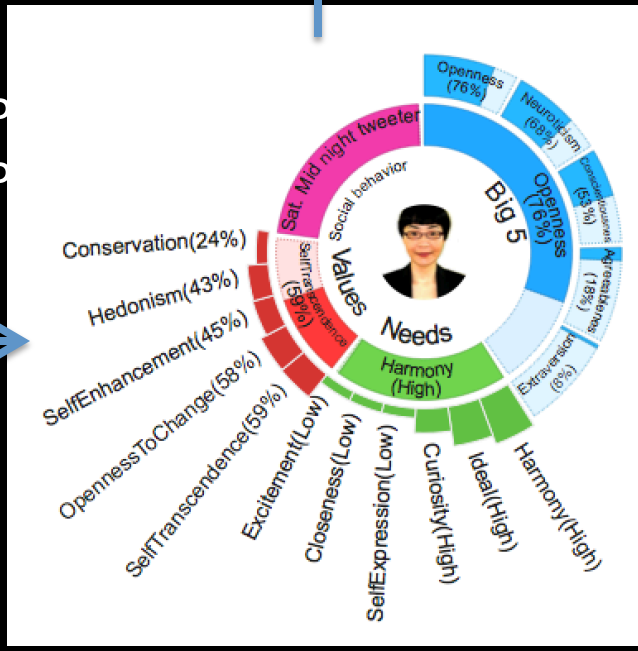
Example: IBM's System U

Engagement Recommendation



Social Media

Psycholinguistic Analytics



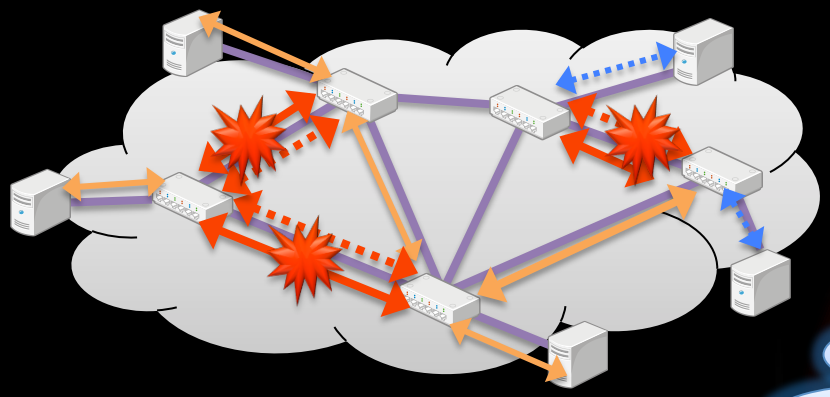
Toward Internet of Everything, NIST

Courtesy: Michelle Zhou, IBM

IT R&D Challenges

1. Privacy and Security/Assurance
2. Interoperability
3. Knowledge Representation (Ontologies)
4. Knowledge/Information/Data Analytics
5. Network Behaviors (IT, Social, Sensors)

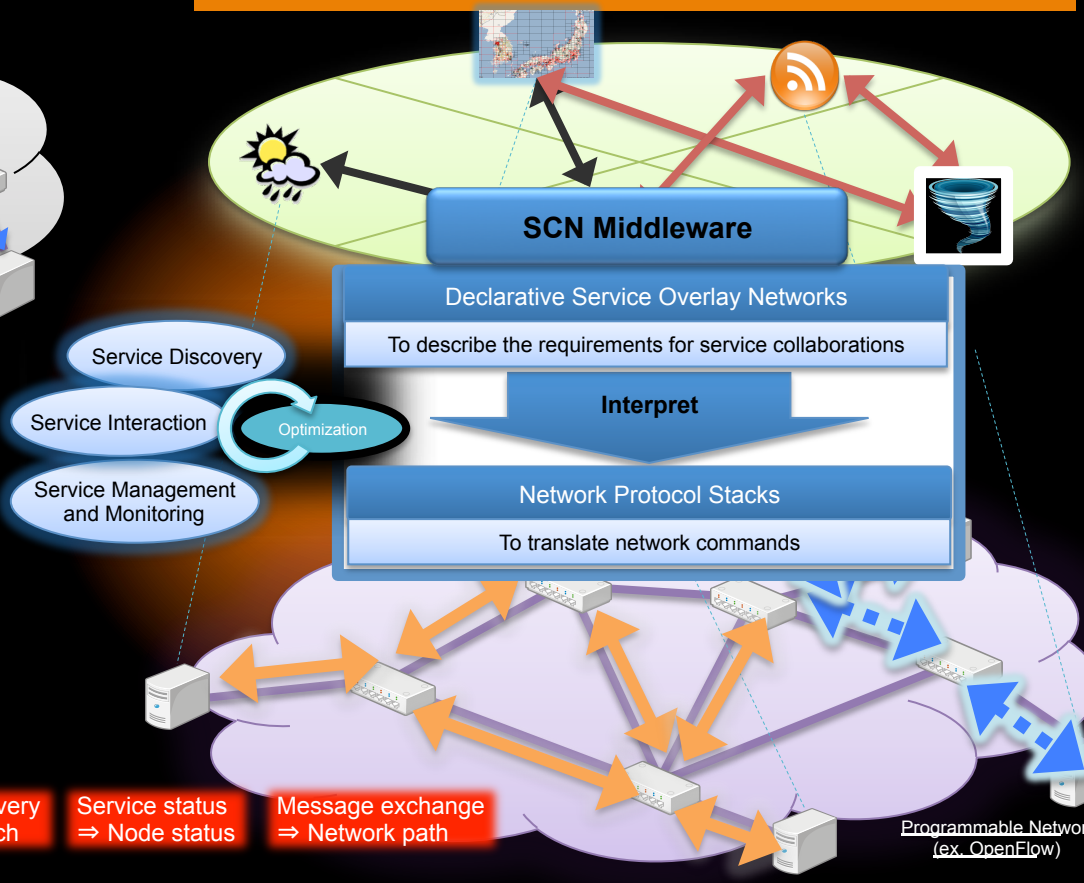
Network Reconfiguration



Rebuilding internet-based infrastructure

- Information (services) migration
- Physical addresses are changed
- Network configuration (ex. flow tables on switch, DNS, etc.)
- Temporary network policies (ex. routing, QoS control, etc.)

Dynamic Network Configuration Technologies



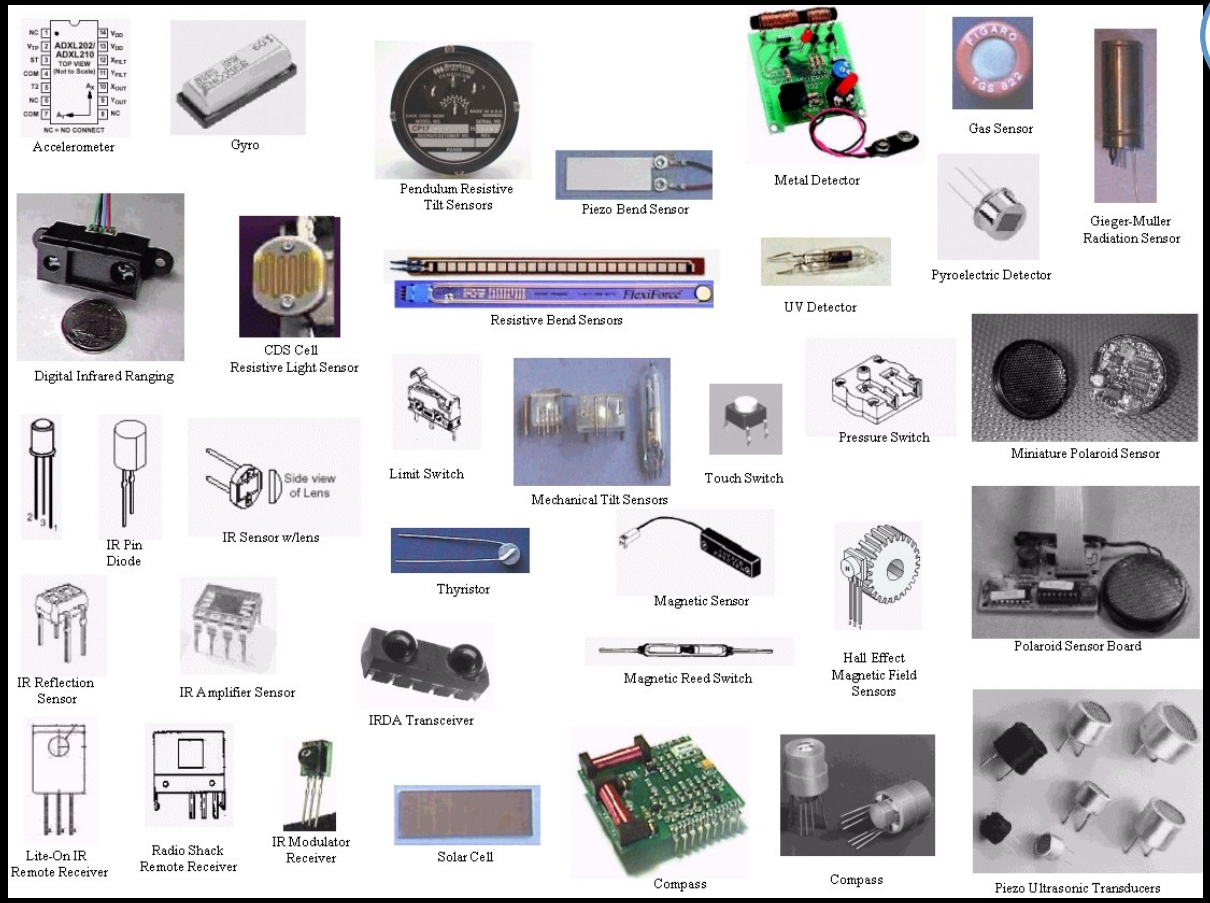
A new technology for precisely and promptly delivering information service requests (i.e., networking requirements) to networks and dynamically adjusting network configurations without much operational cost on the basis of the New Generation Networks

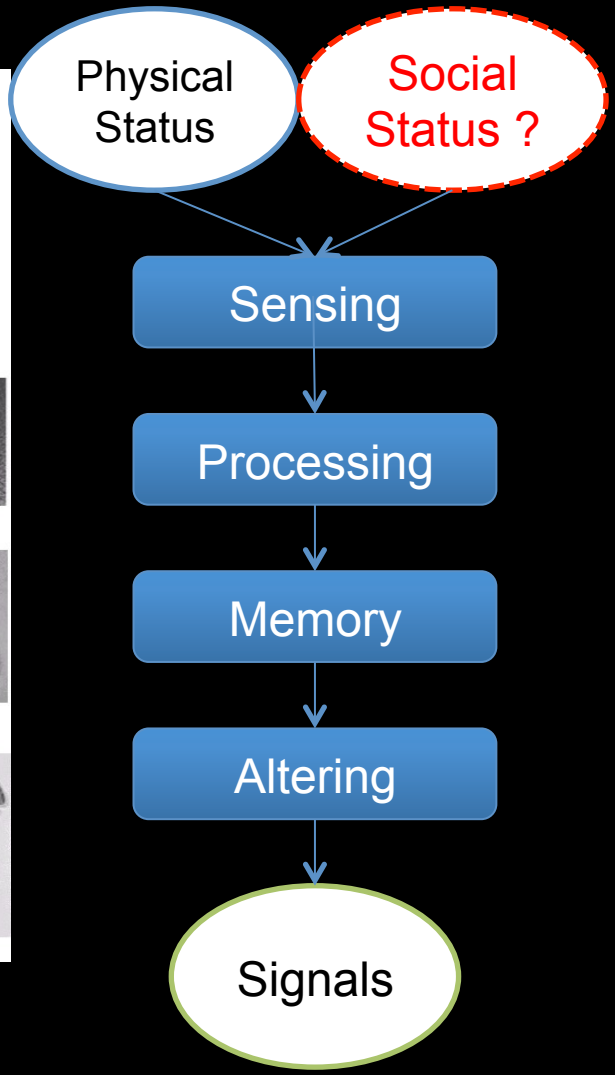
Source: ©NICT NWGN Service-Controlled Networking

Challenges for IT Networks

- Understand complex nature of SNSS networks
- Support evolution of dynamic networks (-- both hardware and software
- Develop measurements techniques to evaluate performance characteristics of SNSS networks
- Predict phase transitions
- Implement prototype demonstrations through testbeds

Re-thinking Sensors to Sense Much More





Toward Internet of Everything, NIST

Ten Primitives for Sensors

1. Sensor
2. Time snapshot (time)
3. Cluster
4. Concentrator
5. Weight
6. Communication channel
7. *e*Utility
8. Decision
9. Geographic location
10. Owner

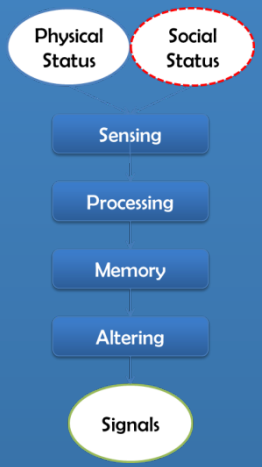
P-Social Sensing Service:
Collecting and Exploiting Data of Social and Natural Phenomena

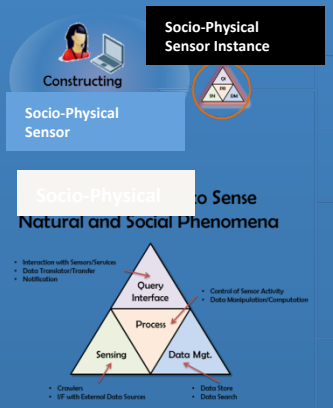
1) Collecting Data for Multidisciplinary Domains Analysis

What's happening to the crowd lives after disasters?

2) Re-inventing Sensors to sense whatever users want

In order to realize Real-World Awareness Services, need Socio-Physical Sensors whose abilities include Social Event Sensing as well as the conventional Physical Status Sensing through various electronic sensors.





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Challenges for Sensor Networks

- Develop algorithms for sensor tracking and manipulation
- Develop ontology of physical sensors
- Identify social sensor patterns for likely scenarios (based on use cases)
- Formulate strategies for dealing with Socio-Physical sensors

IT R&D Challenges

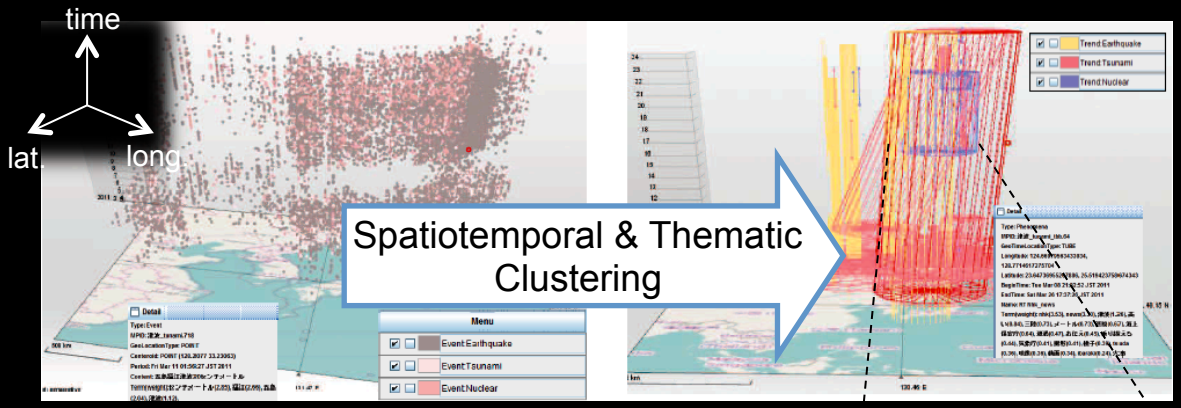
1. Privacy and Security/Assurance
2. Interoperability
3. Knowledge Representation (Ontologies)
4. Knowledge/Information/Data Analytics
5. Network Behaviors (IT, Social, Sensors)
6. Human Computer Interaction

Toward Internet of Everything, NIST

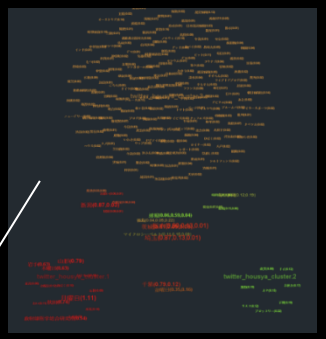
Cyber-Physical Data Visualization

- Mapping and clustering event metadata of cyber data and physical data
  - Cyber data: online documents, Web pages, blogs, SNS
  - Physical data: observation data
- Visual data mining for discovering relations between natural phenomena and social phenomena
  - *E.g.) Baby milk shortage in surrounding area of earth quake along with radiation spread.*

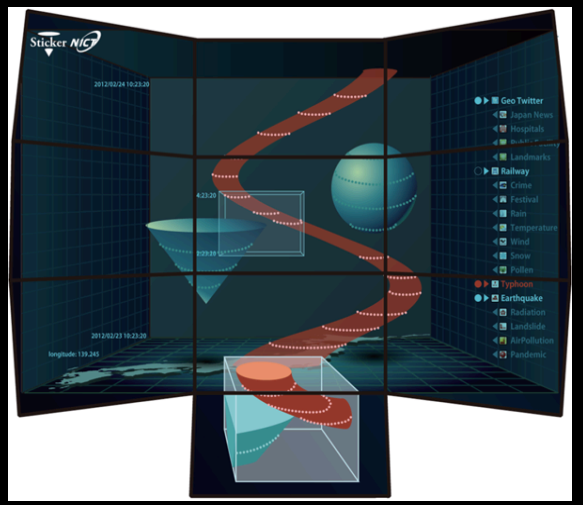
STICKER: **S**patio**T**emporal **I**nformation **C**lustering and **K**nowedge **Ext**R**actor**



Mapping and clustering: (2011/03/02-2011/03/24)
1) earthquake data,
2) tsunami data,
3) nuclear radiation data,
4) geo-tagged Tweets of Tohoku Earthquake Disaster



Twitter keywords in overlapped area



STICKER 3D – Interactive visual data mining using 3D 10-tiled display windows (under development)

Courtesy: Kyoungsook Kim, NICT

Challenges

- Intuitive display of information
- Mental models of users and systems
- Feedback to users about their actions
- Division of labor and responsibility

IT R&D Challenges

1. Privacy and Security/Assurance
2. Interoperability
3. Knowledge Representation (Ontologies)
4. Knowledge/Information/Data Analytics
5. Network Behaviors (IT, Social, Sensors)
6. Human Computer Interaction
7. Architectures (Storage) and Services

Toward Internet of Everything, NIST

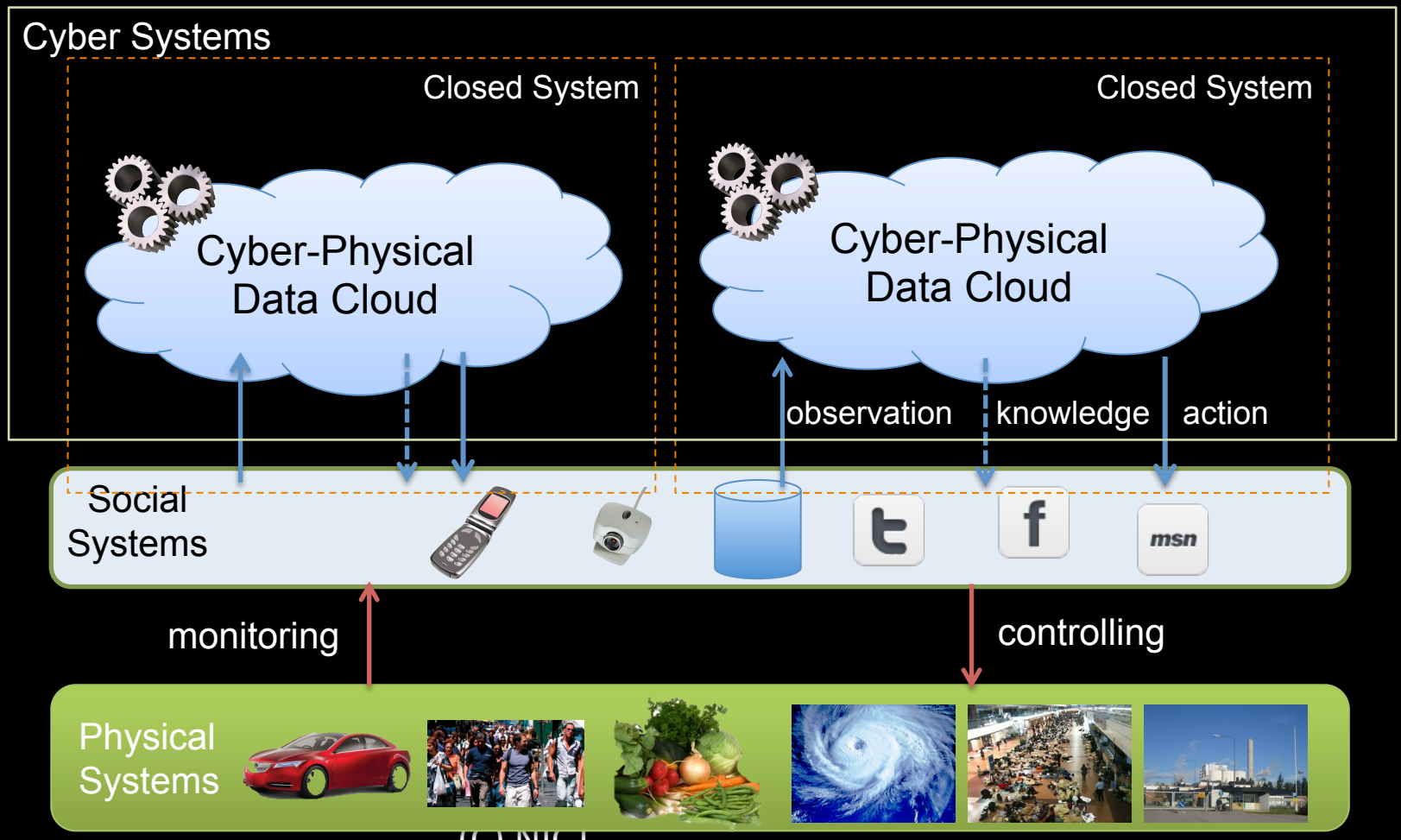
Challenges

- Create multimodal information Architectures (Storage)
- Extend cloud computing research to deal with CPSS/SNSS
  - Architecture
  - Forensics
  - Cloud interoperability
- Implement prototype demonstrations through test beds
- Develop measurement metrics

Cyber-Physical Data Cloud (CPDC) Project

NIST and NICT collaboration project

- R&D for collecting, archiving, manipulating, organizing, and sharing very large (big) cyber-physical social data

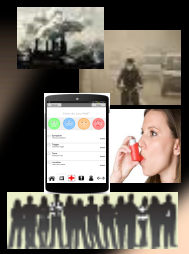


Towards Cyber-Physical Cloud Computing (CPCC)

CPCC Application

Smart disaster response for air quality problem

Event Warehouse



Situation Analysis

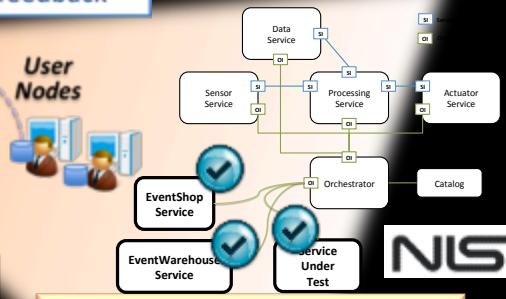
Complex event proce
of cyber-physical-soci
data streams

UCIRVINE

Management
massively-
heterogeneous
sensor data

Actionable feedback

User Nodes



NIST

CPCC Testbed

CPCC Platform

ICT platform for CPCC implementation

Conformance testing of user-defined services

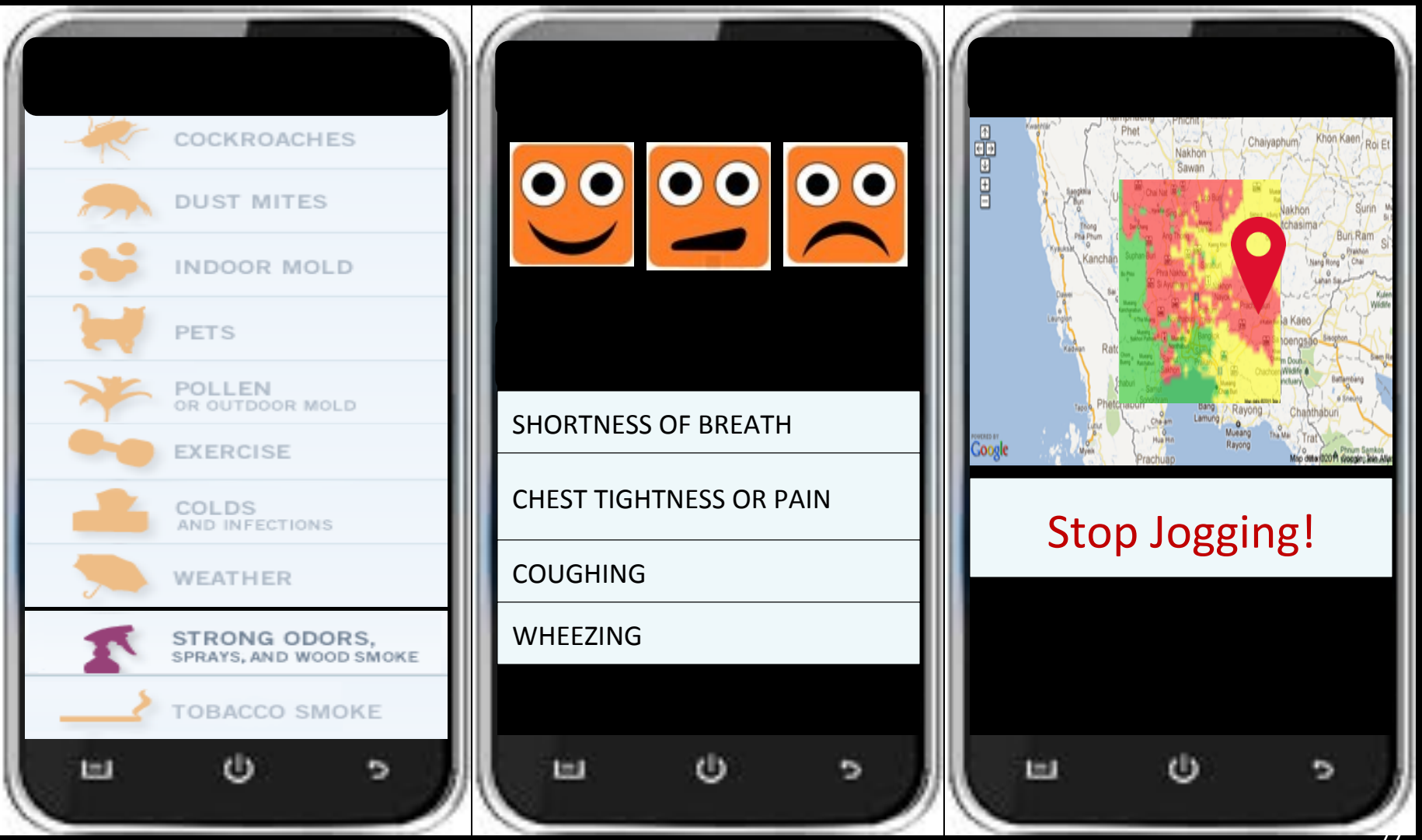
NIST ACTIVITIES

NIST Activities

1. Network of Things (Jeff Voas)
2. Cyber Physical Systems (Chris Greer)
3. Cyber Physical Human Systems (Eswaran Subrahmanian)
4. Cyber Physical Cloud Computing (Eric Simmon)
5. Cyber Physical Social Systems/Smart Networked Systems and Societies (in Collaboration with Ramesh Jain)

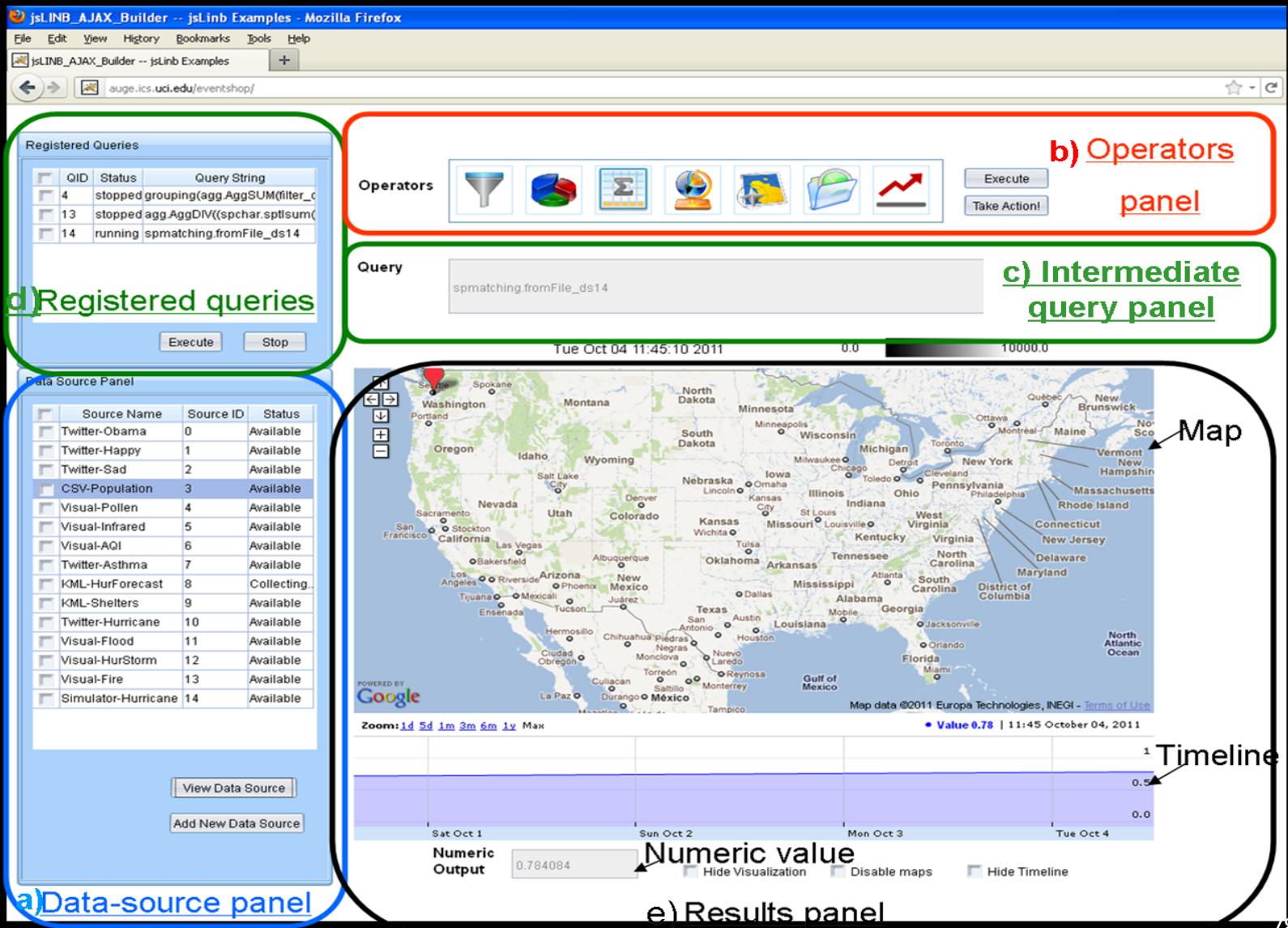
SNSS IN ACTION

UCI Allergy/Asthma App



Courtesy: Ramesh Jain, UCI

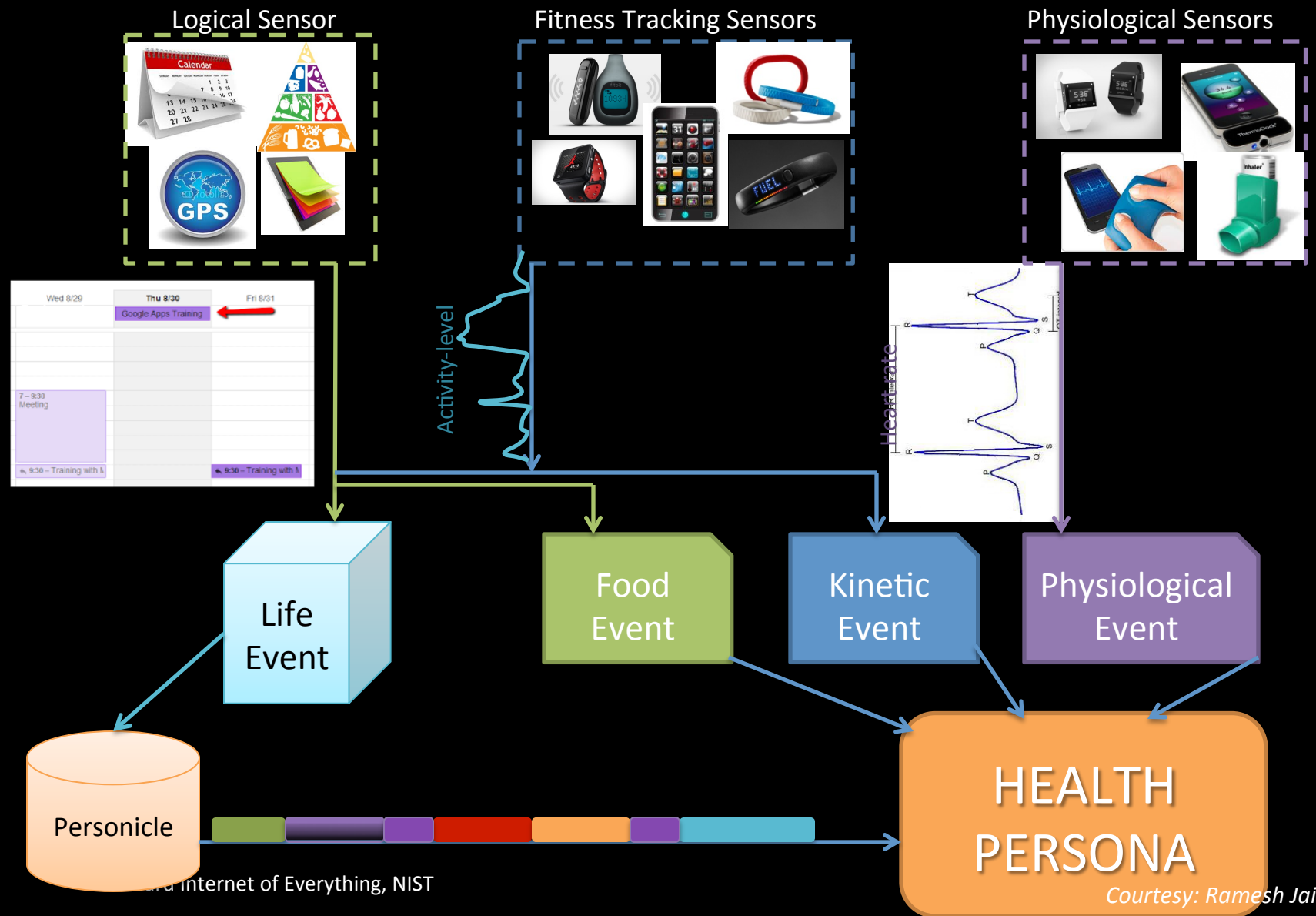
Eventshop: Interaction Environment



http://auge.ics.uci.edu/eventshop/

Courtesy: Ramesh Jain, UCI

Defining Health Persona



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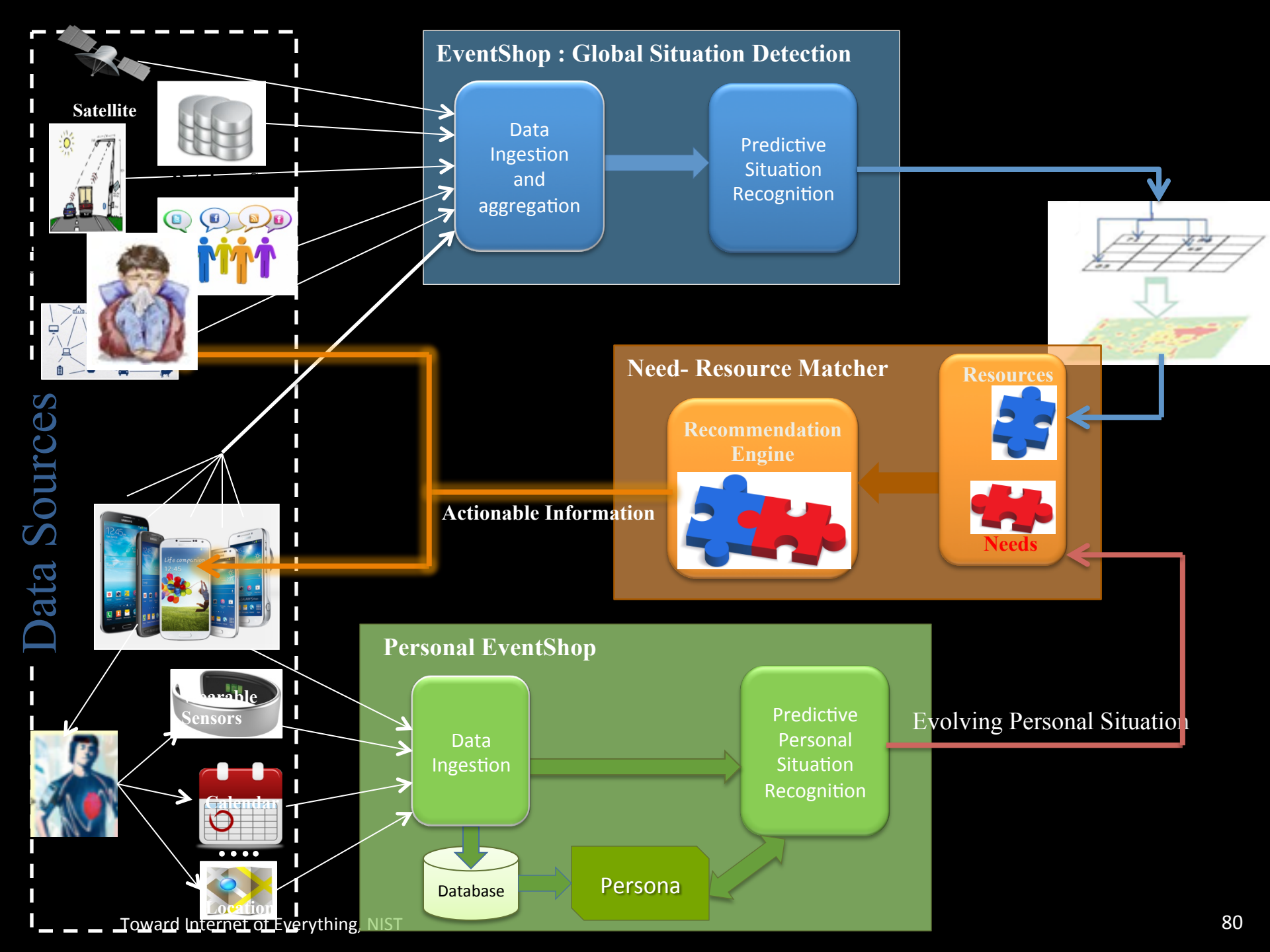
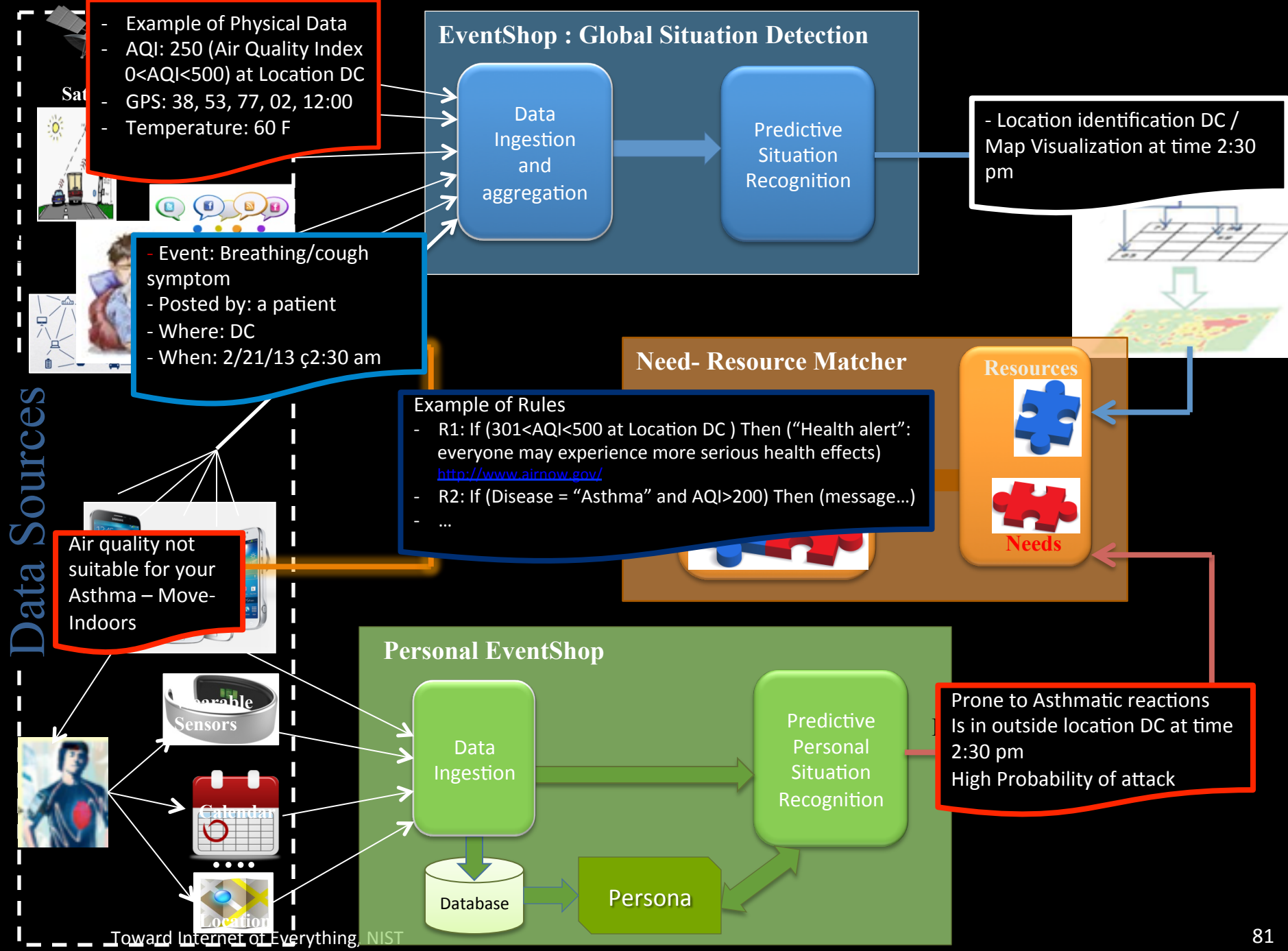
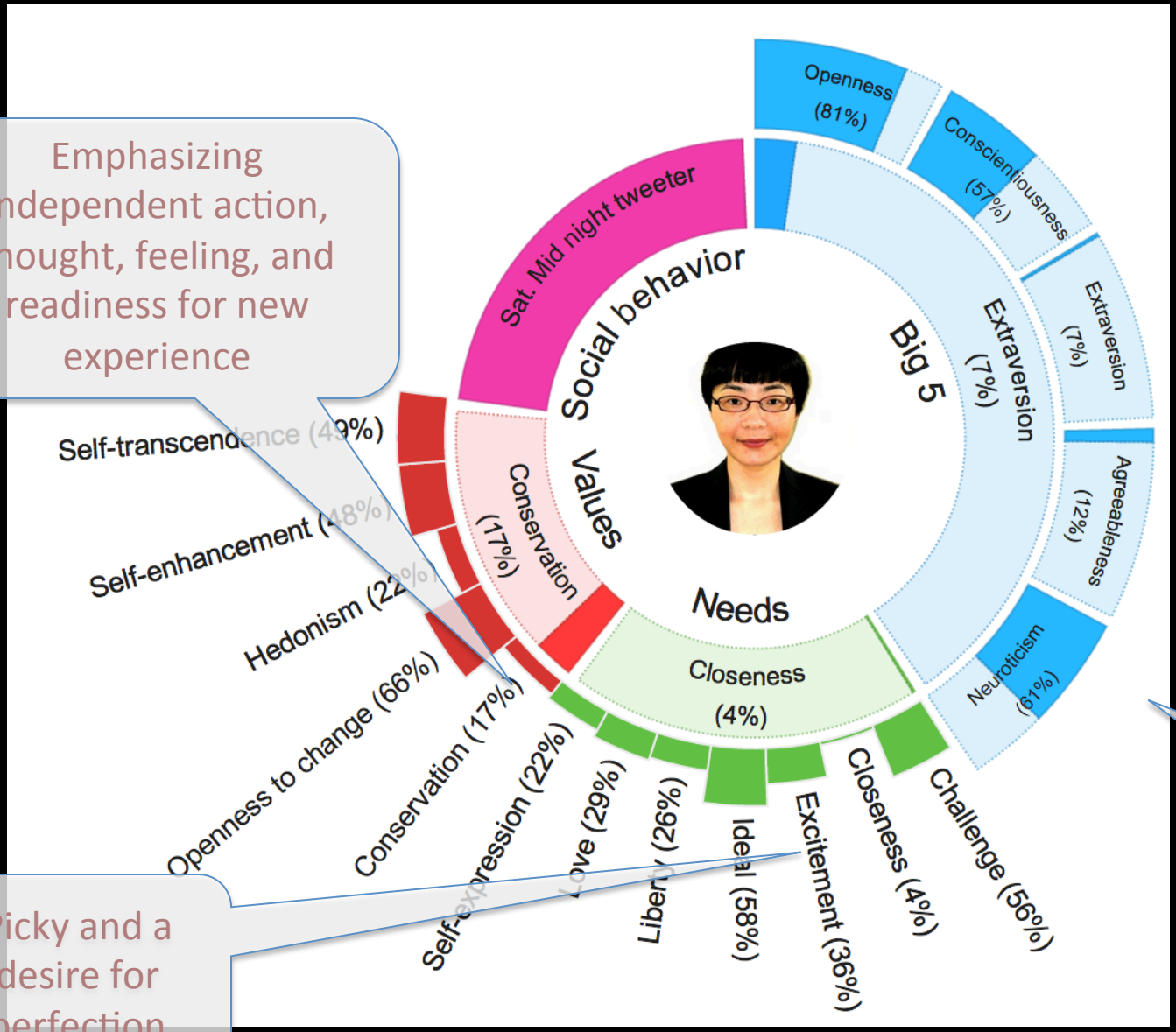
Courtesy: Ramesh Jain, UCI


Data Sources
Satellite
EventShop : Global Situation Detection
Data Ingestion and aggregation
Predictive Situation Recognition
Need- Resource Matcher
Recommendation Engine
Resources
Needs
Actionable Information
Personal EventShop
Data Ingestion
Predictive Personal Situation Recognition
Evolving Personal Situation
Database
Persona
Sensors
Calendar
Location


Data Sources
- Example of Physical Data
- AQI: 250 (Air Quality Index 0<AQI<500) at Location DC
- GPS: 38, 53, 77, 02, 12:00
- Temperature: 60 F
- Event: Breathing/cough symptom
- Posted by: a patient
- Where: DC
- When: 2/21/13 ç2:30 am
EventShop : Global Situation Detection
Data Ingestion and aggregation
Predictive Situation Recognition
- Location identification DC / Map Visualization at time 2:30 pm
Need- Resource Matcher
Resources
Needs
Example of Rules
- R1: If (301<AQI<500 at Location DC) Then ("Health alert": everyone may experience more serious health effects) http://www.airnow.gov/
- R2: If (Disease = "Asthma" and AQI>200) Then (message…)
- …
Air quality not suitable for your Asthma – Move-Indoors
Personal EventShop
Data Ingestion
Predictive Personal Situation Recognition
Database
Persona
Prone to Asthmatic reactions
Is in outside location DC at time 2:30 pm
High Probability of attack
Sensors
Calendar
Location

Personality Portrait: An Example



Courtesy: Michelle Zhou, IBM

Summary

SNSS Harness the Power of :

- Sensors and information sources
- Strongly emerging participatory culture
- Collective knowledge and intelligence of society

Courtesy: Ramesh Jain, UCI

The
FOUR
PARAD
DATA-INTENSIVE SCIENTIF
EDITED BY TONY HEY, STEWART TANSLEY, A

The
Fifth Paradigm
Web & Distributed Innc
Zetta Science

THE
SIXTH PARADIGM
KNOWLEDGE & VISUALIZATION
Singularity Press

The
Seventh Paradigm
Smart Networked Systems & Societies
The World Press

Toward Internet of Everything, NIST

Imagine!

- It took about 30,000 people to build the Taj Mahal
- It took about 100,000 people to build the Great Pyramid
- About 300-400,000 people were involved in putting a man on the moon
- Now, imagine what can the combined intelligence of millions of people on the Internet can achieve!!

Acknowledgments and Disclaimer

- This talk evolved on a concept developed with Donna Dodson (NIST) in 2010
- Thanks to Subrahmanian (Sub), Ramesh Jain and NICT collaborators (Kyoungsook Kim and Koji Zettsu) for many of the slides
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- Some ideas taken from an AAAS panel organized with Vint Cerf

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