Green Networking and Data

- By
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    - “Energy efficient data acquisition“
  - Periklis Chatzimisios, Alexander TEI of Thessaloniki, IEEE Big Data Initiative
    - “Green communications and Big Data”
  - Houbing Song, West Virginia University Institute of Technology, WV, USA
    - “Big Data Standards for Green ICT”

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- Secretary of IEEE ComSoc Communications Systems Integration and Modeling (CSIM) Technical Committee
- Information Officer of IEEE Sustainable Computing Technical Committee
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- Editor, IEEE Communications Surveys and Tutorials
- Senior Member, IEEE
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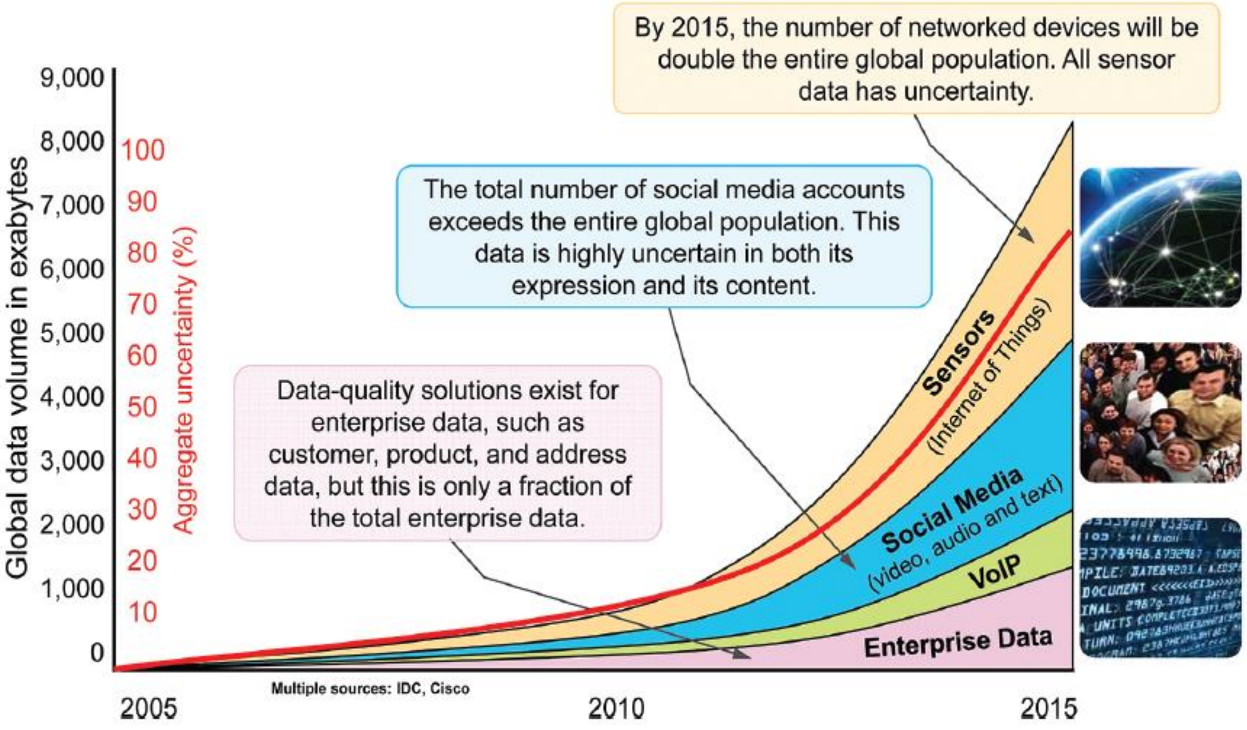
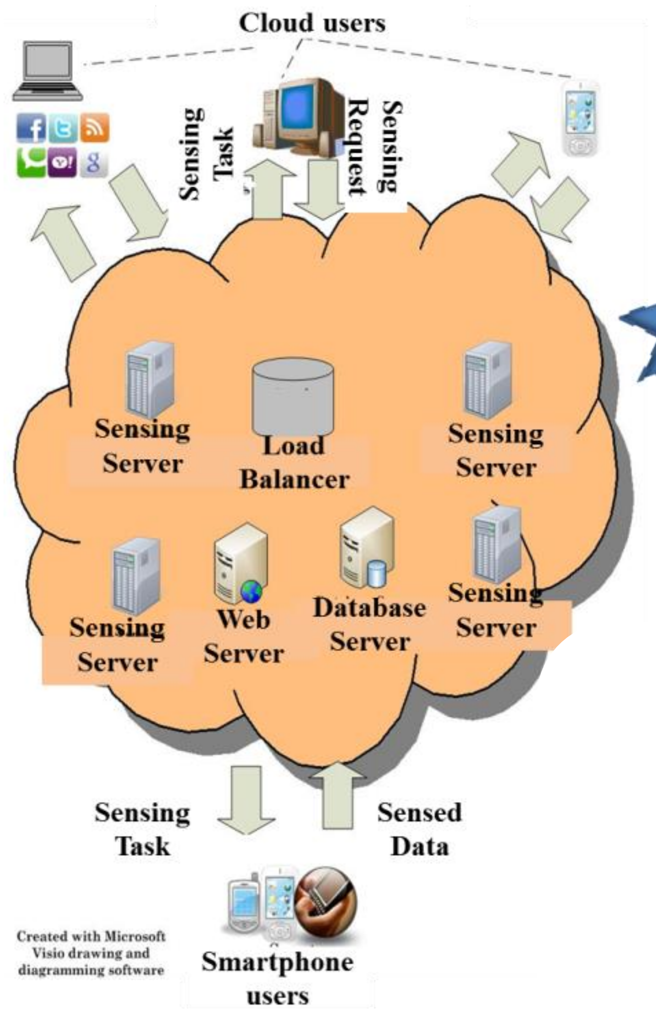
Data explosion and IoT/CPS-driven world (1)

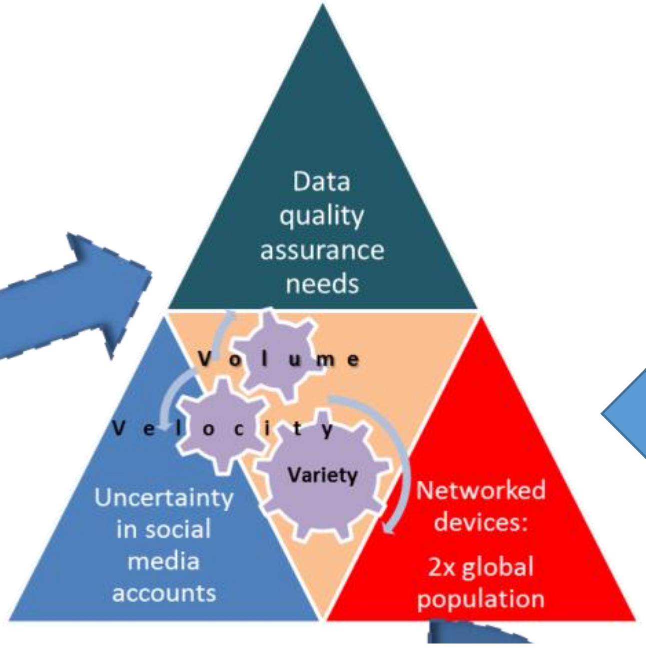


Source: IBM Corp., New York, 2012

- The rise of the need for big data management in the IoT-dominated environment where majority of the data is collected by connected sensing devices.

Data explosion and IoT/CPS-driven world (2)

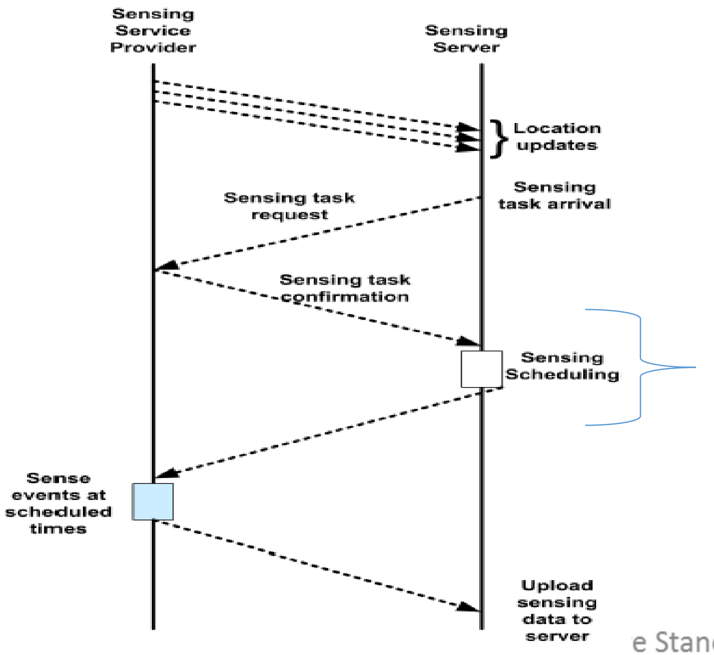




- The rise of the need for big data management in the IoT-dominated environment where majority of the data is collected by connected sensing devices.

Data acquisition under limited battery power (1)

- Smart tablets and smartphones will be the data acquisition interfaces in the IoT/CPS driven big data era
- These devices are constrained to battery power
- Possible solutions: GPS-less data acquisition



Sensing scheduling protocol between sensing server and provider

X. Sheng, J. Tang, X. Xiao, and G. Xue, "Leveraging gps-less sensing scheduling for green mobile crowd sensing," *IEEE Internet of Things Journal*, vol. 1/4, pp. 328–336, Aug. 2014.

EMCSS Scheduling policy:

Objective: Maximum Coverage under battery limitation

FMCSS Scheduling policy:

Objective: Address trade-off between coverage and fairness among sensing service providers

Data acquisition under limited battery power (2)

- Classify sensing tasks as delay tolerant and delay intolerant
  - L. Wang, D. Zhang, and H. Xiong, "effSense: Energy-efficient and cost-effective data uploading in mobile crowdsensing," in *Proceedings of the ACM Conference on Pervasive and Ubiquitous Computing Adjunct Publication*, 2013, pp. 1075–1086.

- Exploit the times when smart phone users place phone calls or use mobile apps so that energy required for sensing is reduced
  - N. D. Lane, Y. Chon, L. Zhou, Y. Zhang, F. Li, D.n Kim, G. Ding, F. Zhao, and H. Cha, "Piggyback crowdsensing (PCS): Energy efficient crowdsourcing of mobile sensor data by exploiting smartphone app opportunities," in *Proceedings of the 11th ACM Conference on Embedded Networked Sensor Systems*, 2013, pp. 1–14.

Data acquisition under limited battery power (3)

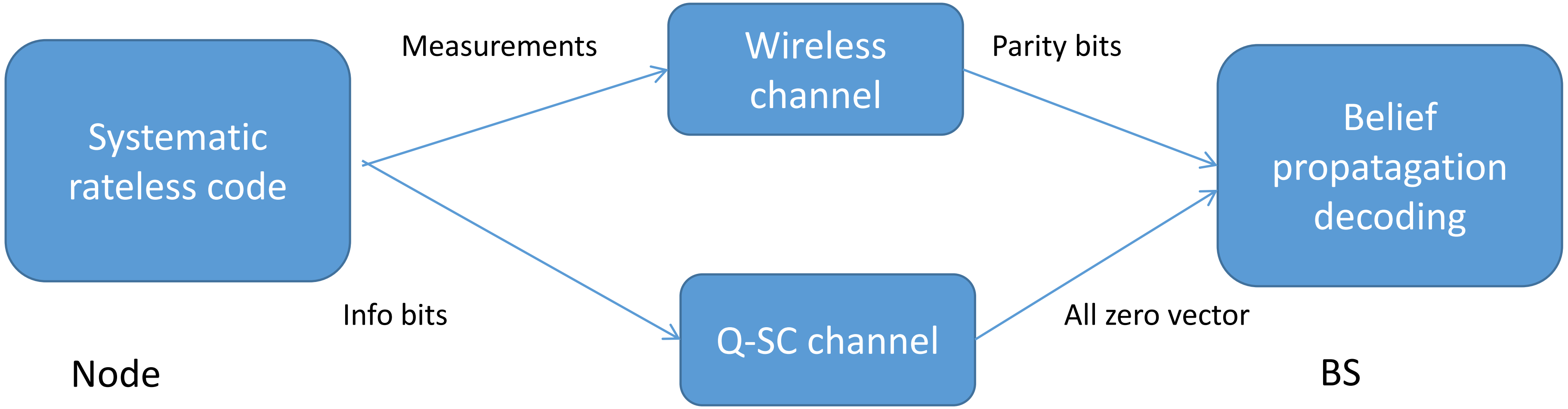
- Smartphones need to be localized for data acquisition
- GPS drains significant battery power
- Localization has to be managed in an energy efficient manner
- Protocol proposals are available
  - Beacon-based protocols
  - Relative location-based protocols

Data acquisition under limited battery power (4)

- Ad Hoc Localization System (AHLoS) for sensing devices
  - Every node contributes to process
  - Small fraction of nodes (beacons) are initially aware of their locations
  - Distributed
    - Robust to surrounding environmental changes
    - Scalable
    - ENERGY EFFICIENT
  - Inter-node ranging uses (RSSI, ultra-sound)
  - Atomic multi-literation is the base case
    - A node uses three anchors in its communication range

Data acquisition under limited battery power (5)

- Adopting compressed sensing in smartphone sensing
  - find a weighted linear combination of samples also called projections in a basis different from the one in which signal is sparse.
- Compressed distributed sensing



Sartipi, M.; Fletcher, R., "Energy-Efficient Data Acquisition in Wireless Sensor Networks Using Compressed Sensing," in *Data Compression Conference (DCC), 2011* , vol., no., pp.223-232, 29-31 March 2011

Potential efforts of a possible research group

Research group on energy efficient data acquisition

- Recruitment for data acquisition
- GPS-less sensor recruitment

Define protocol standards for energy efficient data acquisition

Green communications and Big Data

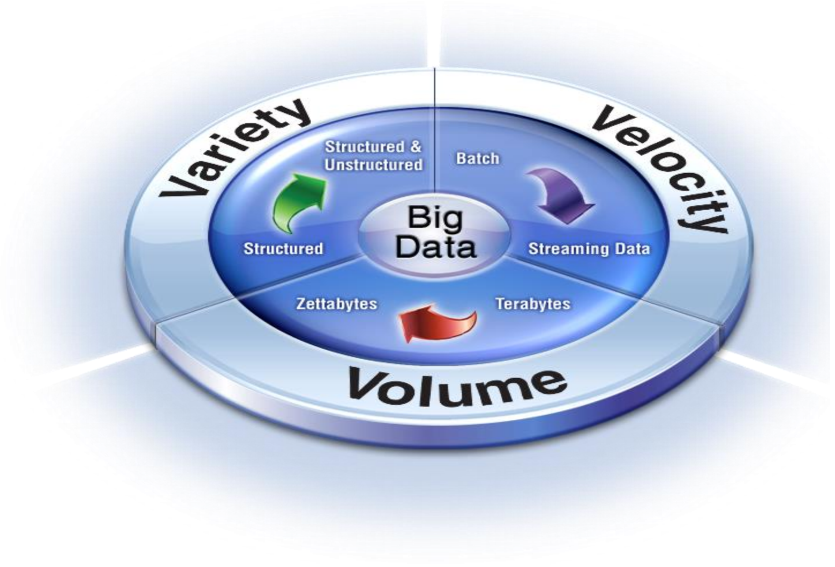
Periklis Chatzimisios (representing IEEE Big Data Initiative)

- ❑ Associate Professor in Department of Informatics, Alexander TEI of Thessaloniki, Greece
- ➢ Member of the IEEE Communication Society (ComSoc) Standards Development Board (since 2010)
- ➢ Secretary of the IEEE 1907.1 Standardization Working Group
- o Vice Chair of the Emerging Technical Subcommittee on Big Data (TSCBD)
- o Ex-Secretary of the IEEE Technical Committee on Cognitive Networks (TCCN)
- o Director for the E-Letter, IEEE Technical Committee on Multimedia Communications (MMTC)

Big Data ecosystem

Big Data characteristics

- ❑ Volume
- ❑ Velocity
- ❑ Variety
- ❑ Variability



Big Data in Energy Domain (1)

- Various application domains exist and each one of them has its own characteristics /requirements and demands different technological and data assets

Target fields

- Electricity production, transmission and distribution
- Distributed production and smart grids
- Renewable energy production
- Energy saving
- Energy policy planning

Big Data in Energy Domain (2)

- Data used in Energy Domain
  - Monitoring/optimizing complex electro-mechanical systems (health monitoring) or energy management systems (optimization based on historic data)
  - Monitoring of energy flow on transmission and distribution grids (smart metering)
  - Forecasting of energy demand and renewable energy production (localized weather, access and analysis of historic data)
  - Monitoring/optimizing/control of Internet connected distributed systems or components
  - Monitoring/optimizing energy management systems
  - Market data

Source: http://www.big-data-europe.eu

Big Data in Energy Domain (3)

- Electricity production, transmission and distribution
  - Utilities/Operators (system monitoring and control, forecasting)
  - Transmission System Operators (grid/substation monitoring, energy flow, smart grids in transmission level, forecasting)
  - Distribution System Operators & aggregators (grid/substation monitoring, AMI automated metering infrastructure, historical data management and forecasting)
- Renewable energy production
  - Manufacturers (fleet monitoring, siting & forecasting)
  - Wind Farm operators (system monitoring, resource forecasting/day ahead bidding)

Source: http://www.big-data-europe.eu

Big Data in Energy Domain (4)

- Distributed production and smart grids
  - Aggregators (grid/substation monitoring, energy flow and balancing, smart metering, forecasting, demand side management)
- Energy saving
  - Industrial sector (energy, large distributed installations)
  - Building & commercial sector (building envelope, audit data, user preferences and behavior)
- Energy policy planning
  - Resource estimation (wind atlases, climate effects etc)
  - Exploitation of socioeconomic/geospatial/legislation data from various sources and formats

Source: http://www.big-data-europe.eu

Challenges of Big Data in Energy Domain

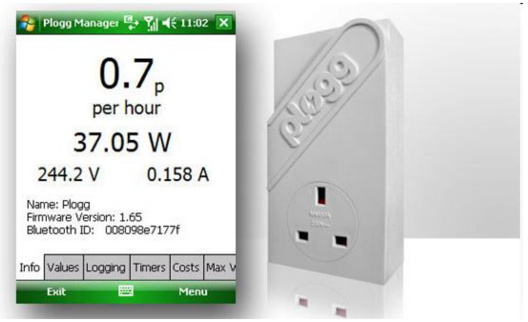
- Competitive low-cost energy production via lower operational and management costs
- Accurate forecasting and grid management
- Expansion and optimal operation of smart grids
- Robust decision making via accessing and processing large data sources
- Exploitation of latest ICT innovation in BD field

Smart Grid and Big Data

- Main applications: Energy management, smart meters, Vehicle-to-Grid (V2G)
- Targets:
  - Forecasting user demand and optimizing energy
  - Shaping customer usage patterns and enable customers to have more control over their energy usage
  - Obtain better understanding of customer segmentation
  - Incorporate distributed generation resources
  - Ensure reliable energy supply and prevent outages
- Challenge: If one reading per 15 minutes is performed in a smart meter we easily reach 96 million reads per day for every million meters

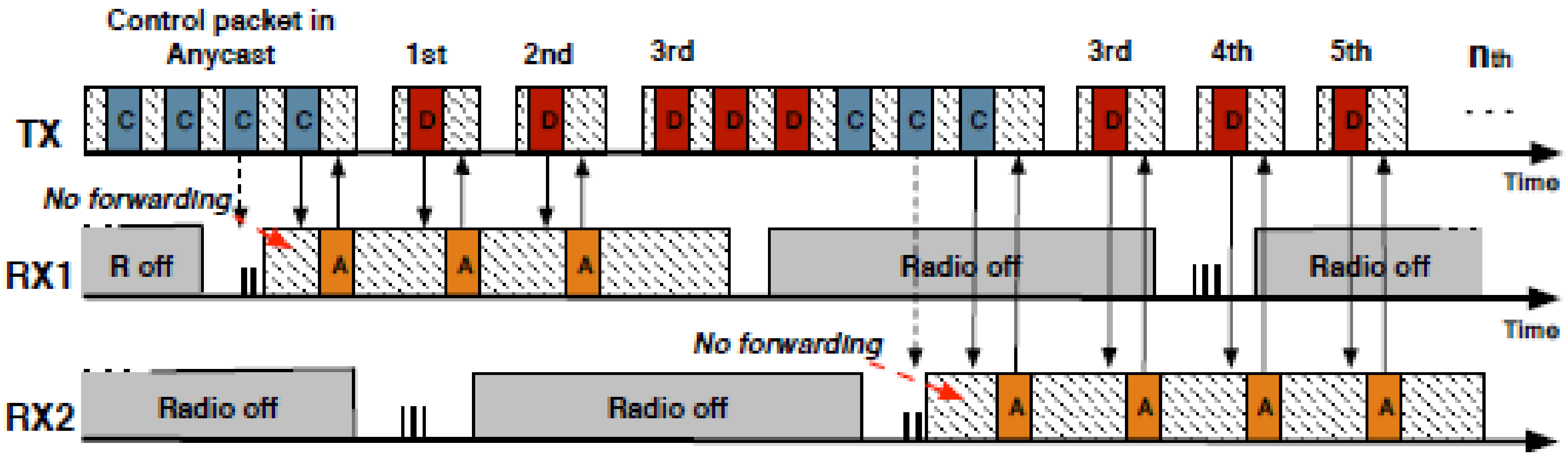
Internet of Things (IoT) is everywhere

Sensor devices are becoming widely available



Challenges in Wireless Sensor Networks

- ❑ Use of mobile sink and/or relay nodes to collect (big) data
- ❑ Optimum clustering (location where data gathering is conducted)
- ❑ Minimize handovers that consume energy
- ❑ Optimization of sleep-awake periods of sensor nodes



What is a standard and why do we need them

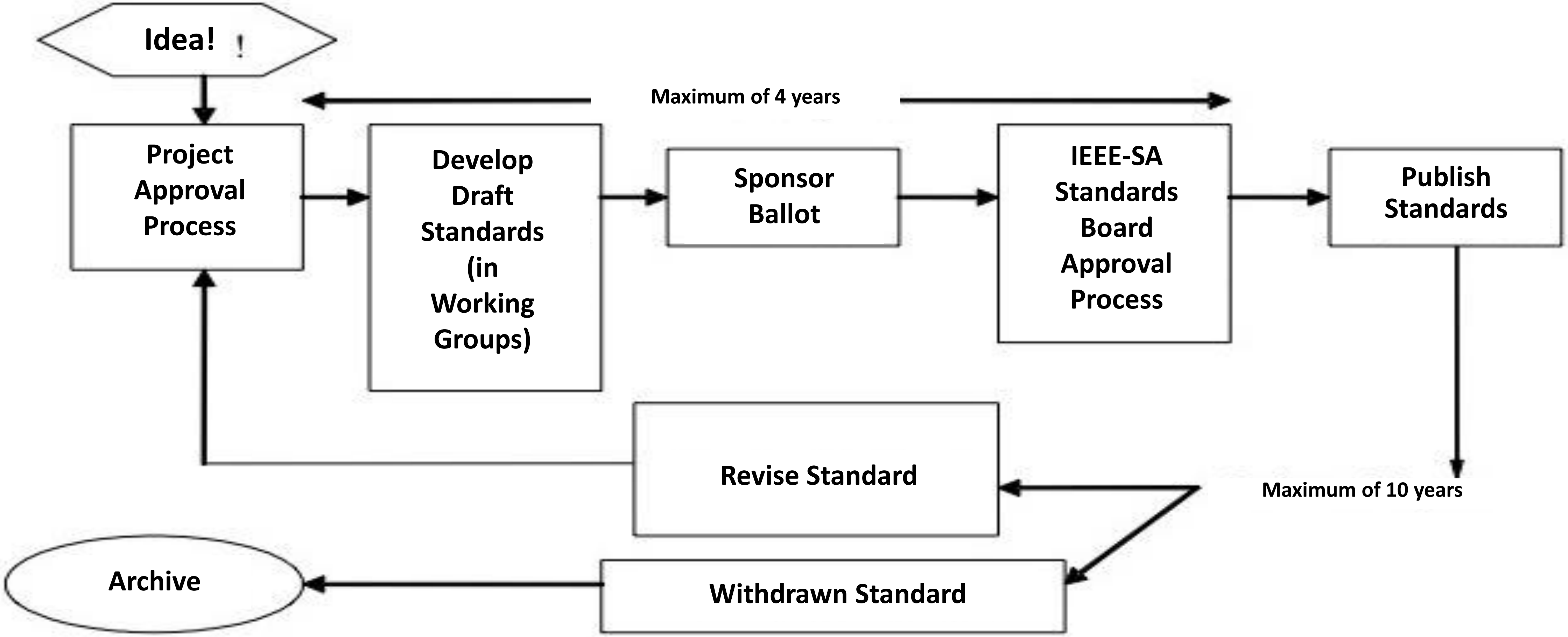
- **Definition: Standards** are published documents that establish specifications and procedures designed to maximize the reliability of the materials, products, methods, and/or services people use every day. Standards address a range of issues, including but not limited to various protocols to help maximize product functionality and compatibility, facilitate interoperability and support consumer safety and public health *(definition by IEEE-SA)*

- **Reasons:**
  - Market Demand
  - Essential for the long term deployment of technology
  - Interoperability
  - Roaming worldwide

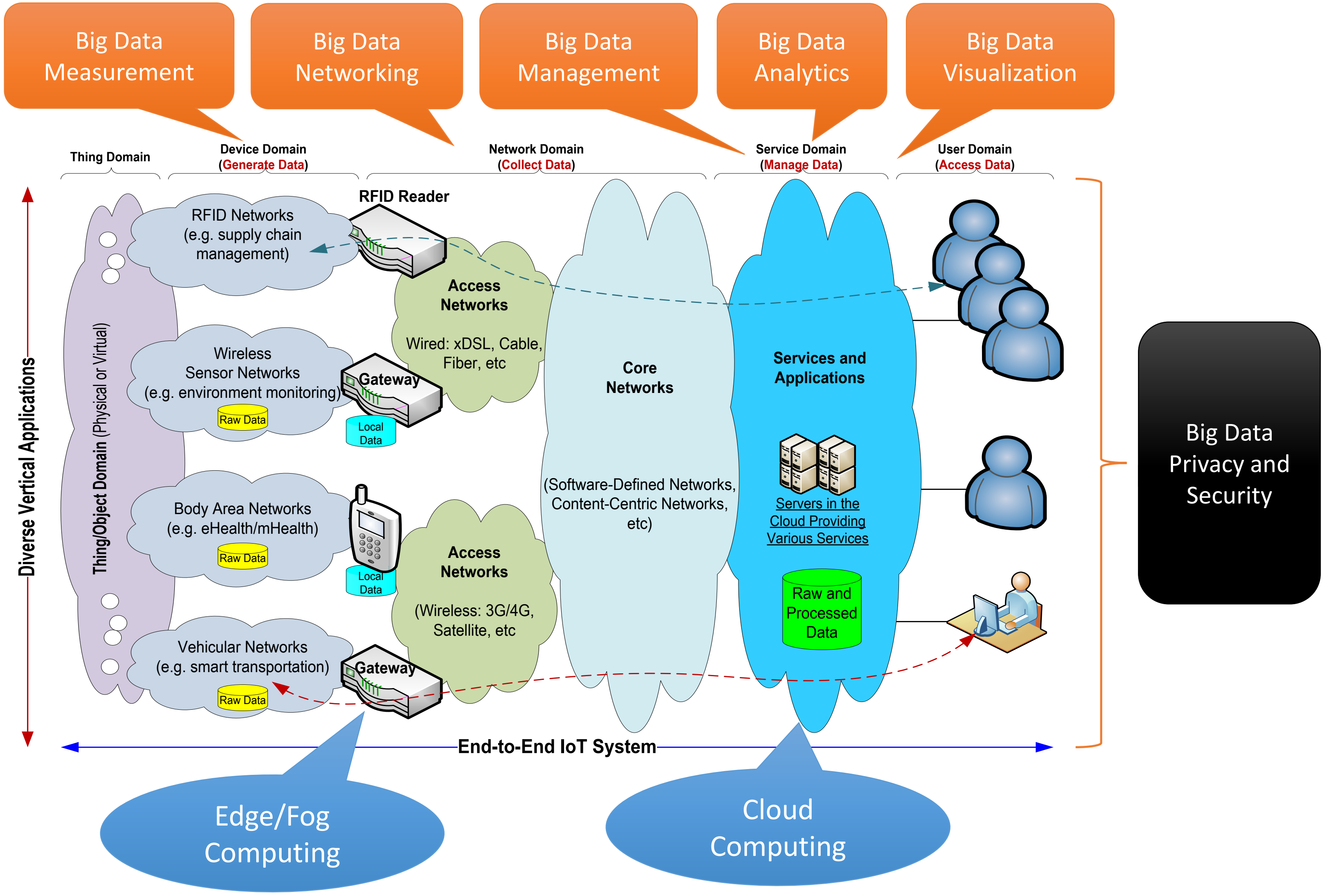
Standards within IEEE

- **IEEE Standards Association (IEEE-SA):** Encourages and coordinate the development process of IEEE standards
- **IEEE Communication Society Standards Development Board (COM/SDB):** Sponsors standards in communications & networking

Standardization process



Conclusion: **It is very long and complicated process!** ☺



Big Data Measurement
Big Data Networking
Big Data Management
Big Data Analytics
Big Data Visualization
Thing Domain
Device Domain (Generate Data)
Network Domain (Collect Data)
Service Domain (Manage Data)
User Domain (Access Data)
Diverse Vertical Applications
Thing/Object Domain (Physical or Virtual)
RFID Networks (e.g. supply chain management)
RFID Reader
Wireless Sensor Networks (e.g. environment monitoring)
Raw Data
Gateway
Local Data
Body Area Networks (e.g. eHealth/mHealth)
Vehicular Networks (e.g. smart transportation)
Access Networks
Wired: xDSL, Cable, Fiber, etc
(Wireless: 3G/4G, Satellite, etc
Core Networks
(Software-Defined Networks, Content-Centric Networks, etc)
Services and Applications
Servers in the Cloud Providing Various Services
Raw and Processed Data
Big Data Privacy and Security
End-to-End IoT System
Edge/Fog Computing
Cloud Computing

Standards gap analysis

The process to perform a standards gap analysis could include:

- Define the requirements
- Identifying existing standards
- Identifying potential standards to be developed/revised

Potential gaps in standardization

- Advanced communication protocols for efficient data transfer
  - Related to ISO/IEC JTC 1/SC 6
- Big Data distribution and cloud computing
  - Related to ISO/IEC JTC 1/SC 38
- Energy cost measurements for Big Data
  - Related to ISO/IEC JTC 1/SC 39
- Cloud computing based data
  - Related to ITU-T SG13

Houbing Song

- Director, West Virginia Center of Excellence for Cyber-Physical Systems (WVCECPS) sponsored by West Virginia Higher Education Policy Commission (HEPC)
- Director, Security and Optimization for Networked Globe Laboratory (SONG Lab)
- Professional Activities Chair, IEEE West Virginia Section
- Senior Member, IEEE
- www.SONGLab.us

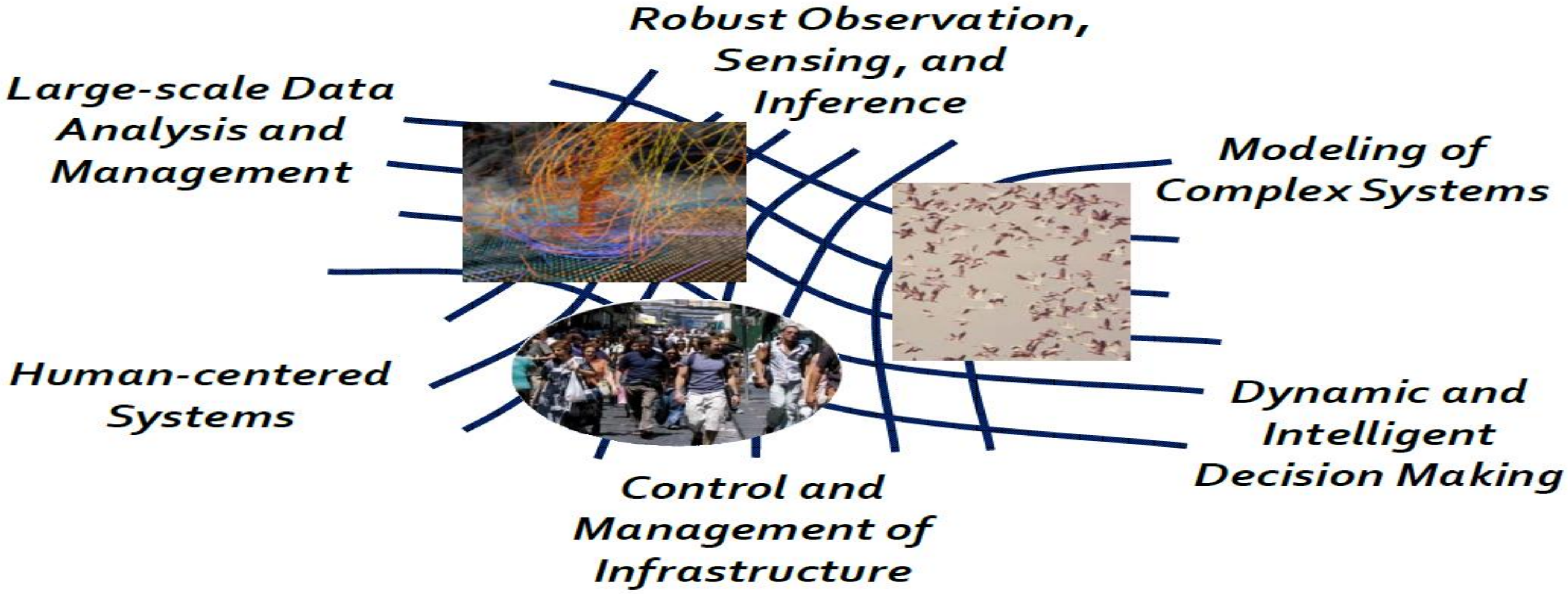
Potential "Green" Applications of ICT

- improving energy conservation
- enhancing energy management
- reducing carbon emissions in many sectors
- improving environmental protection (including mitigation and adaptation to climate change)
- increasing awareness of environmental challenges and responses.

Greening through IT

- Use of computing and IT across disciplines to promote sustainability in areas and systems in which advances in information and communications technology (ICT) could have significant positive impact.

Green ICT


Robust Observation, Sensing, and Inference
Large-scale Data Analysis and Management
Modeling of Complex Systems
Human-centered Systems
Dynamic and Intelligent Decision Making
Control and Management of Infrastructure

Why Big Data for Green ICT?

- Move
  - from descriptive views of data (reporting on "What happened, where, how many?")
  - to more predictive views ("What could happen, what will happen next if…")
  - finally to more prescriptive approaches ("How can the best outcomes be achieved in the face of variability and uncertainty?")
- Move
  - from IoT (sensing and agent end of CPS)
  - to CPS (real-time control through big data analytics)

Big Data for Green ICT-Challenges (1)

- Large-scale
  - New approaches or improvements required in data mining, including clustering, neural networks, anomaly detection, and so on
  - Example: Smart Grid
    - Increasing complexity creates an increasingly complex system of equations that need to be solved on a shrinking timescale in order to create secure and dispatchable energy over larger geographies.
    - a need for improvements in computational capabilities to cope with problems ranging from relatively simple N – 1 contingency analysis, to N – x, to an ability to parallelize the solution to very large systems of sparsely populated matrices and equations that run on high-performance computing systems
  - Appropriate semantic layers needed to bridge various data sources with a common vocabulary and language

Big Data for Green ICT-Challenges (2)

- Heterogeneity of Data
  - Example: Smart Building
    - energy-consumption and outdoor-weather data
    - data on room occupancy, the state of doors and windows (open or closed), thermostat settings, airflows, HVAC operational parameters, building structure and materials, and so on

Big Data for Green ICT-Challenges (3)

- Coping with the Need for Data Proxies
  - meaningful translation of physical, biological, or social variables into an electric signal
  - Example: occupancy in a building may be derived from motion detection, infrared signatures, appliance usage, acoustics, imaging, vibration, disruptions, or other factors, but to varying degrees these may provide only a noisy indication of room occupancy.
  - Example: OTC drug sales and web queries can be proxies for the prevalence of flu.

Big Data for Green ICT-Challenges (4)

- Coping with Biased, Noisy Data
  - Example (Biased): weather and radar data are collected at special locations (e.g., airports) that were likely chosen to reflect the primary purpose of the data, which may be far from ideal for assessing other topics of interesting, such as climate effects.
  - Example (Noisy): longitudinal data (e.g., historical weather records, historical power consumption, historical carbon dioxide concentrations) have been produced by multiple technical generations of sensors and data-collection protocols. Hence, the data are not of uniform quality.

Big Data for Green ICT-Challenges (5)

- Coping with Multisource Data Streams
  - existing statistical methods rely on making strong parametric assumptions about the probability distributions governing the latent variables.
  - How to transform these statistical methods into the kinds of flexible, non-parametric methods (support vector machines, ensembles of tree models, and so on) for non-statisticians and non-computer-scientists to apply easily
  - How to preserve privacy while applying the above transformation methods
  - How to validate hid-den-variable models
  - How to make all of these methods fast enough for interactive use.

IEEE Standards that Support Big Data

- IEEE 2200-2012: IEEE Standard Protocol for Stream Management in Media Client Devices, Approved June 2012.
- IEEE 42010-2011: ISO/IEC/IEEE Systems and Software Engineering—Architecture Description, Approved December 2011.
- IEEE 1808-2011: IEEE Guide for Collecting and Managing Transmission Line Inspection and Maintenance Data, Approved February 2011.
- IEEE 1636-2009: IEEE Standard for Software Interface for Maintenance Information Collection and Analysis (SIMICA), Approved March 2009.
- IEEE P2302: IEEE Standard for Intercloud Interoperability and Federation (SIIF)
- IEEE P2413: IEEE Standard for an Architectural Framework for the Internet of Things (IoT)
- IEEE P3006.8: IEEE Recommended Practice for Analyzing Reliability Data for Equipment Used in Industrial and Commercial Power Systems

ITU-T standard on Big Data

- ITU-T Study Group 13
  - Recommendation ITU-T Y.3600 “Requirements and capabilities for cloud computing based big data, Approved July 2015

Green ICT Standards by ITU

- ITU-T is the standardization branch of ITU
- ITU-T offers the ideal platform for climate change stakeholders to exchange knowledge and expertise with the aim of identifying policy and standard needs to support the integration of ICTs in tackling climate change
  - standardized methodologies to assess the environmental impacts of ICTs
  - universal charger and a universal power adapter (UPA) solution
  - Green batteries
  - energy efficiency (green data centers)
  - framework for using ICTs in adaptation to the effects of climate change

Standardized methodologies to assess the environmental impacts of ICTs

- Recommendation ITU-T L.1400 "Overview and general principles of methodologies for assessing the environmental impact of information and communication technologies"
- Recommendation ITU-T L.1410 "Methodology for the assessment of the environmental impact of information and communication technology goods, networks and services"
- Recommendation ITU-T L.1420 "Methodology for energy consumption and greenhouse gas emissions impact assessment of information and communication technologies in organizations"
- Recommendation ITU-T L.1430 "Methodology for assessment of the environmental impact of information and communication technology greenhouse gas and energy projects"

Universal charger and a universal power adapter (UPA) solution

- Recommendation ITU-T L.1000 “Universal power adapter and charger solution for mobile terminals and other hand-held ICT devices” - ITU-T L.1000 will eliminate an estimated 82,000 tons of redundant chargers and at least 13.6 million tons of CO_2 emissions annually
- Recommendation ITU-T L.1001 “External universal power adapter solutions for stationary information and communication technology devices” - ITU-T L.1001 will save an estimated 300,000 tons of e-waste annually and will reduce CO_2 emissions by between 25% and 50%
- Recommendation ITU-T L.1002 “External universal power adapter solutions for portable information and communication technology devices”
- Recommendation ITU-T L.1005 “Test suites for assessment of the universal charger solution”

Green Data Centers

- Recommendation ITU-T L.1300 “Best practices for green data centers”
- Recommendation ITU-T L.1310 “Energy efficiency metrics and measurement methods for telecommunication equipment”
- Recommendation ITU-T L.1320 “Energy efficiency metrics and measurement for power and cooling equipment for telecommunications and data centres”
- Recommendation ITU-T L.1340 “Informative values on the energy efficiency of telecommunication equipment”

Green Data Centers

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Green Data centers

- Energy savings for servers have been addressed
  - Virtualization
  - Sleep scheduling

- Energy savings for the transport network needs to be addressed
  - Big data does not have to utilize local resources; mostly cloud-based ☺
  - Big data magnifies the energy consumption of the transport network ☹

Proposed Research Groups

- RG-1: Wireless Sensor Networks and Big Data
  - Leader: Fernando Velez, University of Beira Interior, Portugal
- RG-2: Smart Grid and Big Data
  - Leader: Melike Erol-Kantarci, Clarkson University, NY
- RG-3: Energy efficient Data Acquisition
  - Leader: Houbing Song, West Virginia University, WV
- RG-4: Green Datacenters and Big Data
  - Leader: Dzmitry Kliazovich, University of Luxembourg