Technology and Tomorrow: Future Directions... Endless Possibilities

J. Roberto de Marca
2013 IEEE President Elect
IEEE Future Directions Committee Chair
CETUC – PUC/Rio
Intelligent Technologies to Empower Mankind

(USC Ming Hsieh Institute Motto)
Challenges for the Decades Ahead

- Increasing population pressure
  - Water
  - Food
  - Transportation and Mobility

- Energy Consumption
  - 4x growth in last 50 years

- Aging society

- Healthcare needs

- Preserving Human History
World Internet Users: Approaching 2.5 Billion “Online”

Average Annual Growth last three years: a robust 18%

Source: Internet World Stats – www.internetworldstats.com
Internet Traffic Growth: Exabytes ($10^{15}$) per month

Average Annual Growth Rate: 34%

Source: Cisco Visual Networking Index, June 2011
Mobile Internet Traffic Growth: Exabytes ($10^{15}$) per month

Average Annual Growth Rate: **92%**

Traffic Volume Growth – Video Driven

Demand ≠ Bandwidth Availability

Source: Cisco Visual Networking Index, June 2011
Good News: Growth Will Continue: The Internet of (Smart)Things is Coming

- Smart Cities
- Smart Buildings & Homes
- Smart Meters
- Industrial Plants
- e-Health
- Personal Sensors
- Mobile Services
- Storage & Logistics
- Vehicles & Transportation
- Environment Monitoring & Control

Sensing Applications

Internet of Things

Internet of People

10^12

10^9

Courtesy of Roberto Saracco
Internet + Internet of Things =

- Many interconnected objects
- Many tiny transactions
- Value is not in transport but in service

Wisdom of the Earth
GE plans to increase that work force of computer scientists and software developers to 400, and to invest $1 billion in the center by 2015. The buildup is part of G.E’s big bet on what it calls the “industrial Internet,” bringing digital intelligence to the physical world of industry as never before.

Major technologies that animate Google and Facebook are also vital ingredients in the industrial Internet — tools from artificial intelligence, like machine-learning software, and vast streams of new data. In industry, the data flood comes mainly from smaller, more powerful and cheaper sensors on the equipment.

Virtualization of Objects: The Internet With Things

- For each Real Object there will be a representation in the cloud for duplications, synchronization, re-creation of the object, etc.
- Any Virtual Object is uniquely addressable
- Every Virtual Object can be dynamically associated to a User Identity
- Every user can have control over a specific virtualized object or aggregation of objects
- Actions and events on the Real Object act on network images and clones, and vice versa
The Vision

- Connecting the non-physical to the physical
IoT Challenges

- **Evolution of Sensor and actuator technology** (sensibility, power consumption, energy scavenging, etc.)
- **Evolution in sensor networking, protocols, dealing and controlling groups of sensors, addressing, etc.**
- **Impact of DiY**: individuals or crowds of individuals being able to create own solutions and sharing them.
- **Handling (big) data generated by sensors in large smart environments.**
- **Societal Impacts**: how this technology can be effectively used and trusted by individuals, guaranteeing civil rights and stimulating participation
Key Components for Networked Society

1. Sensor Networks
2. Mobile Broadband Access
3. "Big" Smart Pipe
4. The Service Cloud
The Smart Pipe Will Include:

- **Control mechanisms**
  - Providing means for security, policy and traffic management, service control, etc.

- **Mechanisms for enhanced experience**
  - Providing means for personalization, location/presence, etc.

- **Tools for efficiency and enablement**, 
  - Providing support for different business models, and content optimization

- **Very high speed optical transport**, implementation of **Self Adaptive Networks (SON)** concept
  - Required due to mobility support and energy efficiency demands
Growth in Wireless Data Rates

Figure 1. Growth in wireless data rates follows approximately Moore’s Law increasing by a factor of 10 every five years [2].
Major Challenges in Wireless Broadband Access

- A data Tsunami seems to be under way. Video applications and M2M communication will cause an explosion of data traffic.

- Major Overall Capacity Increase (1000x ?) needed.

- Flexible Frequency Spectrum Demand (10x?)
  - Cognitive Radio; Cooperative Multipoint (CoMP); frequency aggregation; use of higher frequencies (28, 38, 60GHz).
Challenges in wireless (2)

- **Is the future of wireless...wireline?**
  - Super dense environments likely (10x more base stations?)
  - Are very small cells the solution?
    - China Mobile has already deployed more than 2 million WiFi Access points (500 M hot spots worldwide in the future?)

- Need air interface data rate increase by a factor of 10 or more early next decade (~10 Gb/s). Target: 1Gb/s peak speed for user
Challenges in wireless (3)

- Significantly lower latency in the air interface
  - New applications will demand this improvement.
  - \( \sim 1s \Rightarrow 1ms \) (Haptic Control, Transportation) \( \Rightarrow 10 \ \mu s \)

- Energy efficiency
  - Needs redesign in all layers of protocol stack
Sensors Everywhere

- Automation and Control
  - Occupancy
  - Noise
  - Motion
  - Ambient light

- Energy usage
  - Water
  - Gas
  - Electricity
  - Heat

- Climate related
  - Temperature
  - Humidity
  - Barometric pressure
  - CO2

- Safety and Security
  - Smoke
  - Fire
  - Carbon monoxide
  - Open-close status
... And More Sensors

- See
- Touch
- Smell
- Hear
- Taste

Adding senses to objects will create a nervous system for the earth

– HP’s “CeNSE”, IBM’s “Smarter Planet” initiatives
Examples of Challenges Ahead

- How to devise transducers that can replicate features critical to sensing shape and texture as needed in touch modality
- Need to have better understanding about neural forms of information signals from all of the senses

Wireless Sensor Networks

- Wireless Sensor nodes must:
  - Have power autonomy (low power)
  - Be small
  - Low cost

- Need for multiple Sensors integrated in a single chip

- Networks must be:
  - self organized
  - based on energy efficient protocols
  - Also delay-aware; mobility-aware
Energy Efficiency: A Tale of Opportunities and Challenges

- **Opportunity**
  - ICT-enabled Emission Reduction

- **Challenge**
  - ICT consumes a lot of energy
ICT-Enabled Emission Reduction

- **Transportation (28%)**
  - Smart logistics
  - Private transport optimization
  - Telepresence
  - Efficient vehicles
  - Traffic control

- **Buildings (31%)**
  - Smart logistics
  - Smart buildings
  - Dematerialization (telecom)
  - Smart grid

- **Industry (14%)**
  - Smart motors
  - Industrial process automation
  - Less waste production

- **Energy (27%)**
  - Smart grid
  - Efficient power generation, combined heat and power (CHP)

Sources: The Climate Group, SMART2020 and M.Decina: Future Networks and Services, ICC 2011, Kyoto
ICT Energy Consumption: A Lot of Bad Indicators

- > 5 billion wireless terminals…and growing
- > 500 million Internet servers
  - 34% annual expected growth in IP traffic
- Energy consumption growing at 16–20% per year
  - Doubling every 4 years
- Energy consumed by telecommunications infrastructure + Internet is:
  - Equivalent to 2-3% of overall electric consumption
  - 10% of total power in some developed countries when the addition of private ICT equipment is factored in
    - Equal to total energy production in some developing countries
- Will energy problem increase the digital gap (again)?
Trends in Energy Costs, Consumption Rates

Fig. 5. Trends in energy costs and consumption rates over the last two decades [27], [28].
Figure 3. *Global carbon footprint of mobile communications projected until 2020.*

*IEEE Communications Magazine, August 2011*
ICT Energy Consumption: Opportunities

- Innovative, energy efficient ICT solutions will be crucial
- New network architectures, network topologies
  - based on high density, low power microcells + relaying
- Electronics/signal processors/devices
- New physical and MAC layers optimized for energy efficiency
- Solutions for optimization problems where energy efficiency will be one of the criteria along with spectral efficiency and performance metrics
What Should You Not Leave Home Without?

- The American Express card?
- Your home and car keys?
- Your wallet?
- None of the above

- In the future the last answer will probably be the correct one!
You Should Not Leave Home Without Your (Future) Mobile Device!!!

- Knows:
  - You and what is around you
- Learns:
  - What you like
- Discovers:
  - Things relevant to you
- Filters:
  - Out the irrelevant

Massive scale computations (billions of simultaneous transactions) needed to mash up personal data, preferences, real world data, and device capability

Courtesy of M. Dècina

Sources: from Qualcomm, USI, 2010
Interesting Concept for the Future: Collective Intelligence

Sensors + networking capabilities

Participatory sensing

Collective Intelligence
Another Bold Vision for the Future!
Google Goggles
Key Components for Networked Society

- Sensor Networks
- Mobile Broadband Access
- "Big" Smart Pipe
- The Service Cloud
A “Cloud” Definition
(Joe Weinman)

- **Common**
  - Resources are shared by customers

- **Location-independent**
  - As long as latency requirements are met

- **Online**
  - Resources are connected to customers via a broadband network

- **Utility**
  - Usage-sensitive pricing scheme

- **on-Demand**
  - Resources are available on demand

Source: Green Telecom Live, “Full Interview: AT&T’s Joe Weinman”
Different Aspects of the Cloud

Application
- Monitoring
- Content
- Collaboration
- Communication
- Finance

Platform
- Object Storage
- Identity
- Runtime
- Queue
- Database

Infrastructure
- Compute
- Block Storage
- Network
Relevant Questions Regarding Cloud/Utility Computing

- How much IT will move to the cloud?
- Will concepts like *The World is my Data Center* and *Cloud Everything that is Not in your Desk* prevail?
- Need to move from centralized Clouds to highly distributed and networked clouds
- How will security concerns be addressed?
- Will flat rate or pay-per-use predominate?
- How will cloud providers make money?
- Will IT spending increase or decrease?

Source: J. Weinman, IEEE TTM 2011
Applications that will benefit from the Networked people + things environment

- Smart Grid/Power
- **Smart Living**
  - Smart Buildings
  - Intelligent transportation systems (ITS)
  - E-health
- Safety and Security
What Is The Smart Grid?

The Smart Grid integrates sensing, information technology and advanced communications into the power system in order to:

- Increase system efficiency and cost effectiveness
- Provide customers tools to manage energy use
- Improve reliability, resiliency and power quality
- Enable use of innovative technologies including renewables, storage and electric vehicles

Courtesy: G. Arnold
Smart Grid Electricity Infrastructure

Fig. 2. Future grid expansion at the customer site.
A Glimpse Into the Future

What disruptive innovations are on the horizon?

- Demand Management
- Distributed generation
- Energy Storage
  - A top 10 problem
- Electric Vehicles
- Interoperability standards

Courtesy: G. Arnold
Technologies Will Be Fully Connected

- ICT
- Energy Efficiency
- Smart Grid
- Smart Living

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Smart Cities

• Smart City is ICT being applied for the benefit of Society.

• A Smart City involves: Communication, Mobility and Transportation, Energy Efficiency, Public Services, Urban Security and Urban Management

• Smart City Nervous Systems: M2M communication platform.

• Latency is critical (~1ms) for Transportation applications
Aging Population and Increasing Demand for Health Care

- Telemedicine
- Ambulatory health monitoring
- Fall detection
- Ambient assisted living

Smart environments to improve quality of life
Future Scenario

- Smart Grid
- Smart appliances
- Independent living
- Lighting Control
- Intelligent spaces
- Smart Home and Building
- Smart city
- Intelligent traffic
Intelligent Transportation Systems

**VIDEO CAMERA:** Mounted near the rear-view mirror, the camera detects traffic lights and any moving objects.

**LIDAR:** A rotating sensor on the roof scans the area in a radius of 60 meters for creation of a dynamic, three-dimensional map of the environment.

**POSITION ESTIMATOR:** A sensor mounted on the left rear wheel measures lateral movements and determines the car's position on the map.

**DISTANCE SENSORS:** Four radar sensors in the front bumper and one in the rear bumper, measure distances to various obstacles and allow the system to reduce the speed of the car.
Intelligent Transportation Challenges

- Continued progress of sensor performance and cost
- Faster computers to handle the large and growing amount of data
- Legal framework needed for having a completely autonomous unmanned vehicle in real public traffic
  - Who to sue: the driver (not in control) or the car manufacturer?
ITS Challenges (Cont.)

- Better ways to correct classifying obstacles, included water-based ones
- Solutions for adapting the vehicle’s behavior to the owner’s personal style
- Better handle difficult interaction between autonomous vehicles and other traffic participants, both robots and humans
- More research on cognitive systems to reach a higher grade of autonomy
Technologies Will Be Fully Connected

ICT

Energy Efficiency

E-Health

Smart Buildings
eHealth

- Stressors on Healthcare
  - Access
  - Demographics
  - Costs

- Technology
  - Cloud Computing
  - Mobile connected devices
  - Advanced displays
  - Data Models-data driven model

Shen, S. (2011, June) *eHealth: How IT trends will shape the future of healthcare*, presented at IEEE TTM 2011, Hong Kong
Examples of e-Health Services

- Worldwide unique electronic health record for each patient
- Mobile Patient Folder
  - Electronic folder carried by nurses or doctors when visiting patients
- Remote Patient Monitor
  - To support assisted self-care
  - Patient health data can be actively monitored by nurses at hospital
- Wearable Intelligent Sensors
- Distance training of medical personnel
- Remote consultancy by advanced center doctors
Biomedicine and Neuroscience

Doctor-on-a-chip
- Cell phone info repository
- Monitoring, remote intervention and services

Body-Area Networks

The brain as a wireless network
- EKG signal reception/modeling
- Signal encoding and decoding
- Nerve network (re)configuration

Source: A. Goldsmith, Stanford Univ.
CHIC (CHip In Cell)

- Autonomous, wireless, implantable sensor
- Active, continuous-time monitor of cellular activity

Source: T. Johnson, B. Reutter

Source: Ada Poon, Future Implantable Systems, IEEE TTM 2011
A Prediction Regarding Implantable Devices

- Implantable systems will revolutionize health care in the coming decades
- Potential applications include:
  - Implantable sensors and monitoring devices for preventive and post-surgery monitoring
  - Drug delivery systems that can be placed closer to cancer cells and are able to administer dosage automatically
  - Medical robots that perform surgery inside patients with greater precision and less pain
  - And many more...
Prosthetics

Key Question:
- How Do We Make Future Neurally Integrated Prosthetic Devices Speak The Same Language As The Nervous System?

Source: R.E. Cummings, IEEE TTM 2011
Grand Challenges in Life Sciences

- Utilize new technologies to create a precision, personalized medical practice which is able to treat each patient individually.
- Restore functionality to injured/missing organs, limbs and nervous systems using both intelligent prostheses and enhanced biological processes.
- Integrate engineers and physical scientists more fully into life sciences research and translational medicine.
- Bring engineering and computer science knowledge and techniques to bear on organizing, visualizing, and utilizing biological 'big data'.
- Employ emerging nanotechnologies to streamline the discovery, testing, and approval of new drugs and treatment methodologies.
Additional Challenges

- **Improve Data Collection** – needed in order to apply existing engineering theory and tools such as control theory.

- **Develop Nano-scale Devices** – to enable measurements of cellular level biological signals, to follow individual cells through their lifespans.

- **Develop more realistic, precise models** at multi-scale levels, integrating genomics, body networks, cell, tissue, organ, and population.
Enabling Technologies

- Digital Content generation and interfaces
  - Augmented Reality
- Evolution in Displays (OLED, flexible, etc.)
- Advances in semiconductors, nanotechnology
- Development of Natural User Interfaces
- Energy Storage
Gracias!
Questions or Comments?
New Technology Connections
Landing Page

- New technology landing page is a first step towards improving the presence of the technology initiatives on IEEE’s main site and establishing a more unified user experience for those seeking technology information.
New Activities In IEEE Future Directions

- Green ICT
  - Chair: Jaafar Elmirghani, University of Leeds

- Enhancing the performance of multicore computer systems
  - High Performance Computing

- Internet of Things
Important Research Areas

- Wireless Sensor Networks (WSN)
- Machine to Machine communications (M2M) or object to object communications
- Scaling issues in a trillion-node intelligent network spanning the Earth
- Energy efficient design methodologies for every network component
LTE Throughput Analyses

**Fig. 9.** Expected throughput for LTE with 4 × 4 antennas (left) and derived throughput losses, absolute (middle) and relative (right) at 5-MHz bandwidth, pedestrian B channel.
Smart Buildings: Present Day (Digital) Homes

- Broadband Internet Access (often including a WiFi Router)
- Digital Video Equipment
- Diverse Telecommunications Equipment
- Audio/Music Equipment
- No networking among devices