HALOS Networks: a Competitive Way to Internet of-with Things

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Imagine a rainy day...

- Imagine a rainy day and observe raindrops falling on the pavement...

Imagine a rainy day…

- Initially wet regions are isolated. Progressively these wet regions are becoming connected and we can find a wet path interconnecting them
- This happens suddenly when there is a critical density of raindrops…

- **Welcome to Halos Nets !**

- Imagine “halos” centered around people, vehicles, street lamps, kiosks etc, embedding Wi-Fi communication, and also storage and processing resources
  - for example, a halo could include a set of sensors and actuators plus controllers, tiny PCs and a smartphone (acting also as a Wi Fi router): a halo is a sort of Wireless Personal Area Network (WPANs) centered around a workspace or entity
- A critical density of halos is creating suddenly a fully connected network which is emerging spontaneously through overlapping halos

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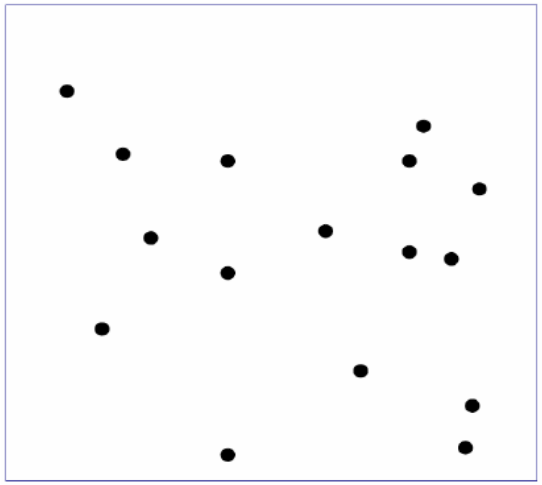
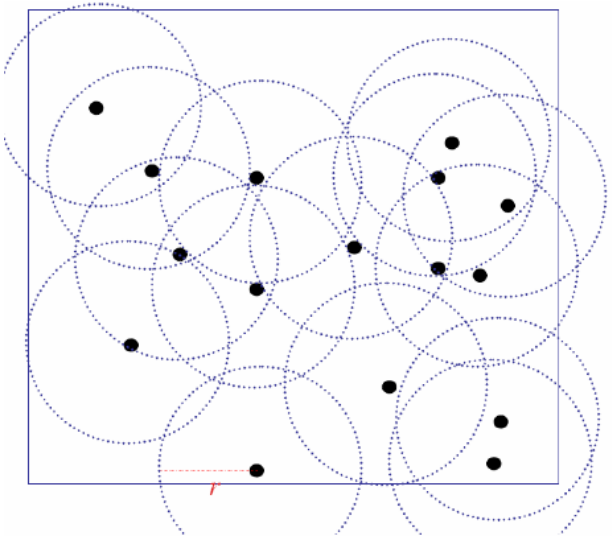
… halos can flock together

- Short-middle range connectivity can be covered hop-by-hop by local device-to-device communications, whilst long range interactions can be enabled by hopping into the big Net
- Services and data can be delivered virally through multiple things, devices, machines, objects mostly by using local resources
- …not only, having the Halos makes also a clone on the Cloud…





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Anything will be a WiFi node !

- Intel has just unveiled a WiFi sliver of silicon that can be part of a normal microprocessor chip.
- As of today, WiFi chips were separate from the microprocessor because of specific needs of the radio part.
- This is the first time that someone (Intel) has come up with an industrial manufactured chip embedding radio on the chip.
- We can expect that wherever we find a microprocessor (e.g. in over 70% of toys, to name just one area) we will find embedded connectivity.

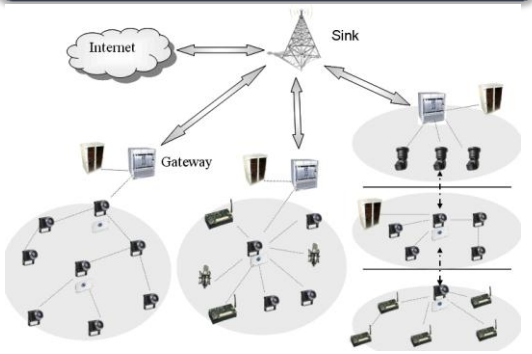
Roberto Saracco
http://www.blog.telecomfuturecentre.it/

Other important trends…

- Modern smartphones and tablets have significant storage capacity often reaching several gigabytes… this trend will continue in the future, coupled with down spiraling costs
  - e.g. device to device communications and the sharing of storage capabilities can significantly reduce mobile capacity bottlenecks: backhaul connectivity can be (partly) replaced with storage capacity…
- Heterogeneous Networks for expanding mobile network capacity…
  - HetNets are typically composed of multiple radio access technologies, architectures, transmission solutions, and base stations of varying transmission power.
- Smaller and smaller cells…femtocells, picocells, and microcells.
  - Complexity is increasing creating the need of self-organizing networks.

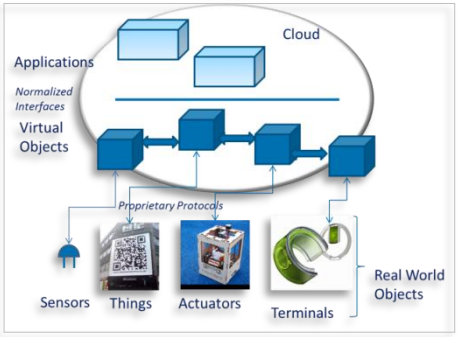
Paving the way towards Internet of-with Things

IoT



IoT foresees billions of "things" communicating and interacting with each other

IwT



IwT foresees billions "virtual objects" becoming accessible to people through the Internet

importance of the object and its reachability: it is a gate to access "services"

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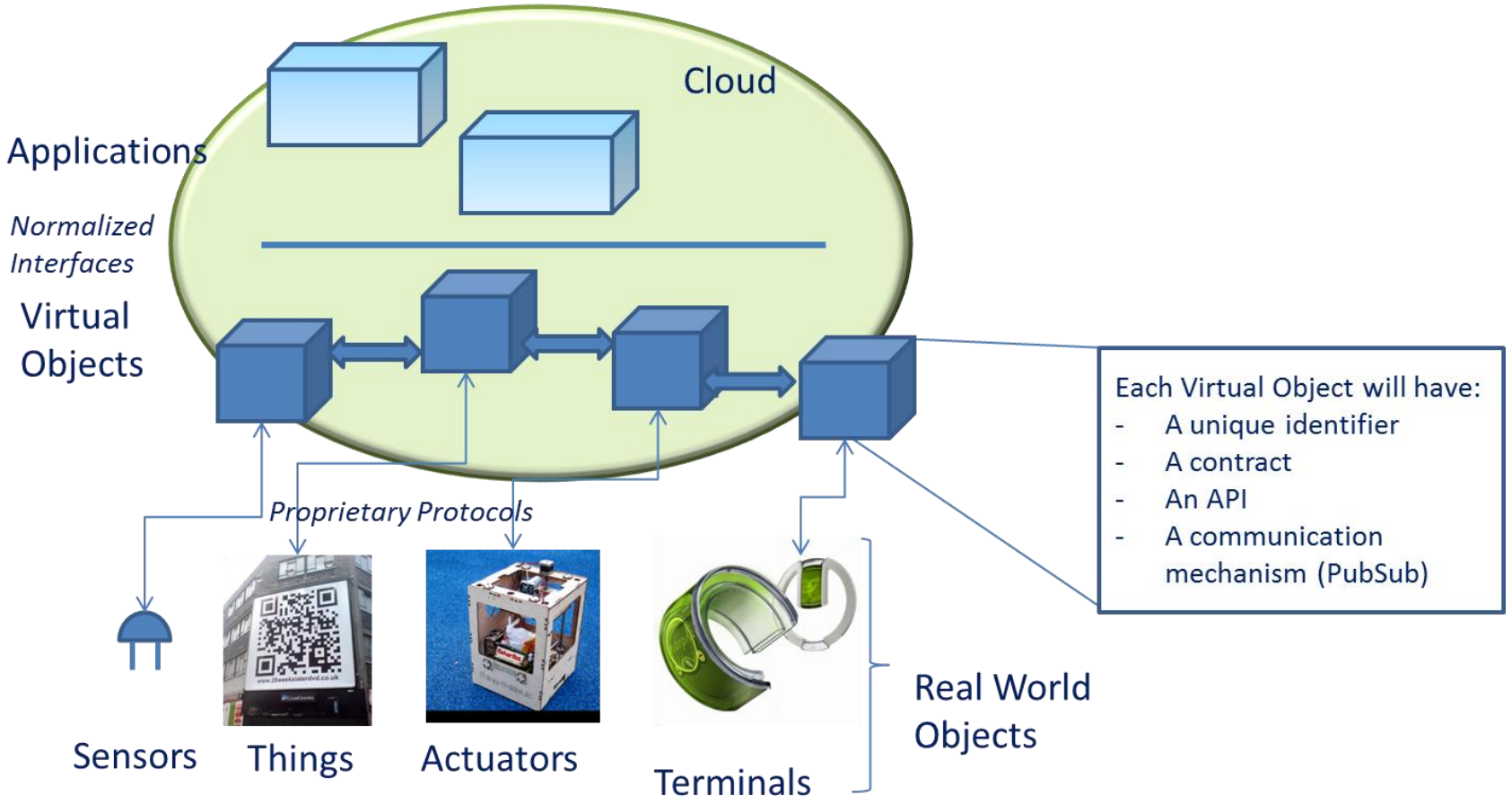
Internet With Things



Internet(s) embedded in everyday life !

Mark Weiser

- ***"The most profound technologies are those that dissappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it."***

- **Creating new environment by embedding into objects computing, storage and communication capabilities, gracefully integrated with people:**
  - **Real Things (IoT)**
  - **Virtual Things or Clones (IwT)**

(*) Scientific American, Vol. 265 N.9, pp. 66-75, 1991

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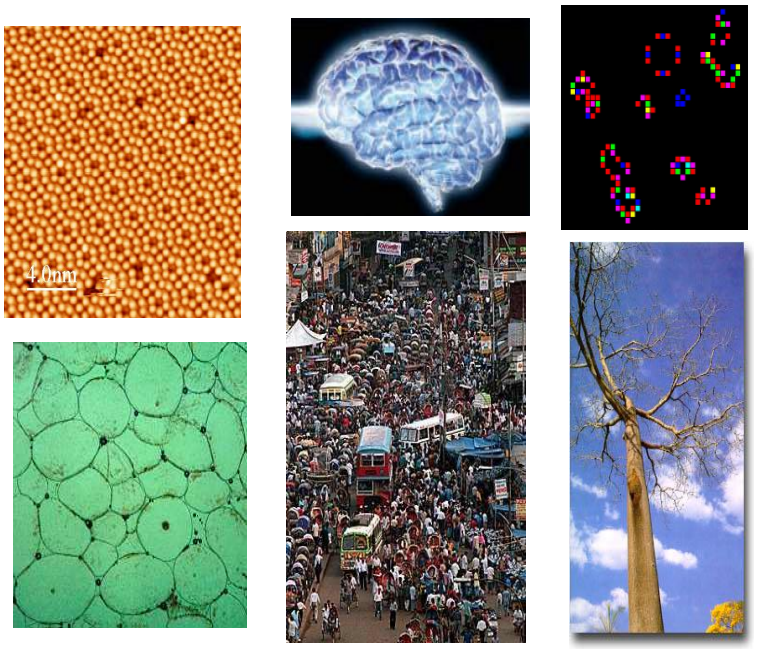
This is creating a great level of Complexity

- **Complex Adaptive System (CAS) are systems composed by a sheer number of interacting components. Typical phenomena are:**
  - **Self-Organization: emerging of global properties out of local interactions**
  - **occurrence of phase transitions which are sudden transformations of a system, evolving from one phase to another**

- **Examples of CAS:**
  - **A crowd of people**
  - **A nest of ants**
  - **The brain**



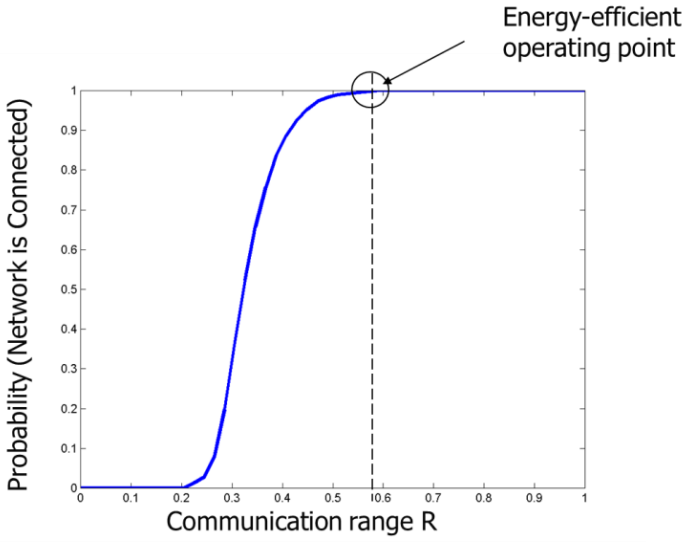
Examples of Complex Systems

Is a singularity near ?

- **Singularity: a *period during which the pace of technological change will be so rapid, its impact so deep, that human life results irreversibly transformed.***
- **Unlimited and low cost processing, storage and communication capabilities are creating the conditions for a singularity in future ICT.**

Is a singularity near ?

- For a certain number of nodes, and for a critical communication range, the probability that a Halos Network is fully connected shows a sudden transition 0-1
  - This transition provides also the energy efficient operating point
  - Mathematically demonstrated



$$P_n(R) = \prod_{i=1}^{n-1}(1 - e^{-\lambda R}) = (1 - e^{-\lambda R})^{(n-1)}$$

- Two examples:
  - Super connectivity
  - Super throughput

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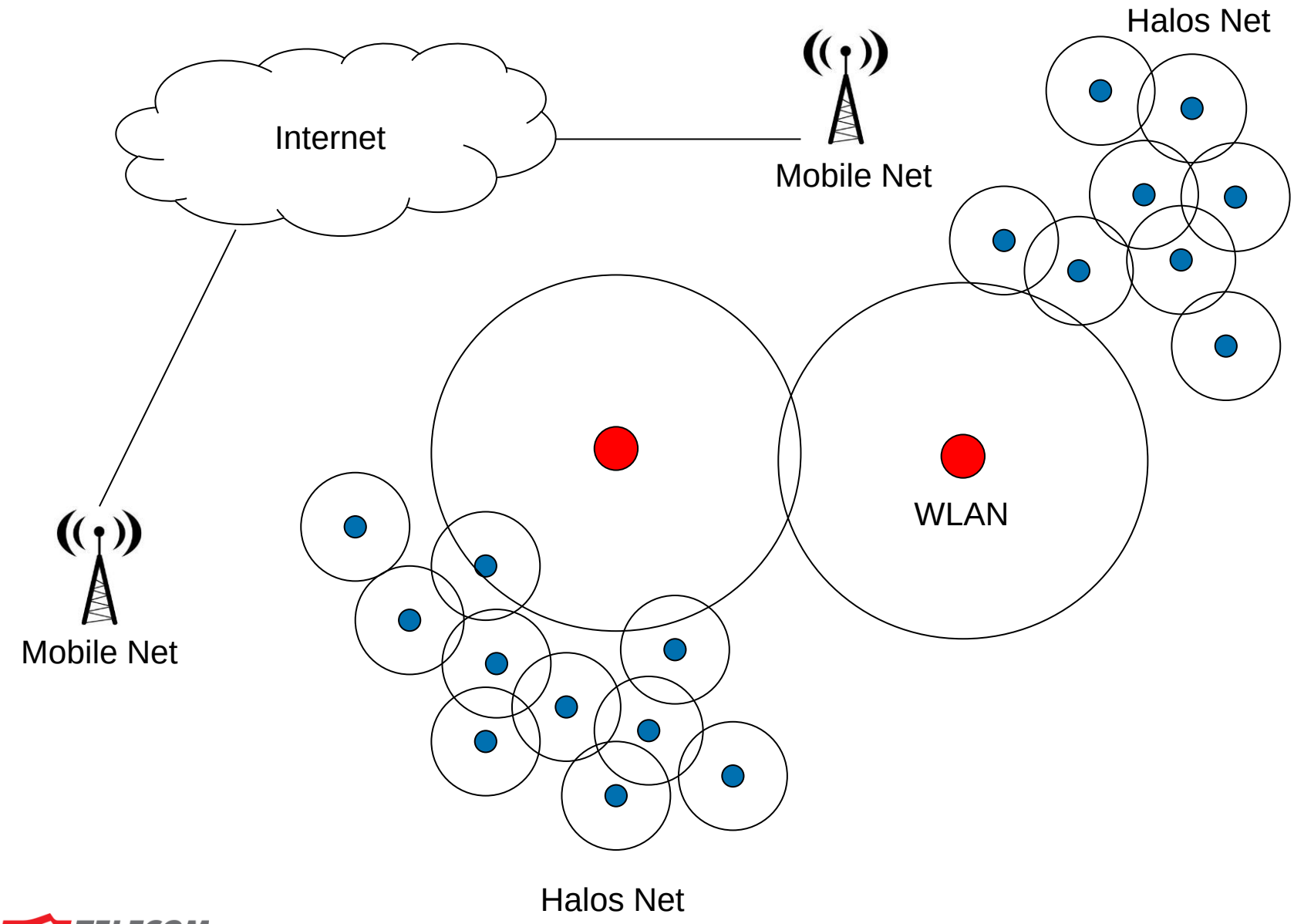
Is a singularity near ?

- **Super connectivity:**
  - **a sheer number of simple low cost nodes with a limited radius of local communication is able to provide an enormous wireless capacity:**
    - **theoretical capacity is proportional to the square root of the network size (number of nodes): e.g., one million nodes with available bandwidth of 1 Mb/s can reach a total capacity on order of Gb/s**
    - **under the hypothesis of "ergodic" node mobility the capacity can be even linear in the number of nodes**
- **Super throughput:**
  - **Sharing of storage and processing resources abruptly provides an enormous capacity**
    - **for a certain number of nodes, and a critical level of resource sharing, the overall throughput of the network shows a sudden transition to enormous capacity**

Open Challenges

- Why this is not happening in today Wi-Fi networks? Space capacity tends to decrease with the number of nodes, rather than increasing…
  - …Wi-Fi medium access protocol (MAC), primarily designed for wireless LANs, does not scale to multi-hop networks
  - …there are performance bottleneck related to routing
  - …issue of overhead: every node must inform all other nodes about its local connectivity
- MAC is difficult mainly because of the difficulties to send and to receive at the same time
  - Interference situations at receiver affect transmission success, but can be very different to what the sender can observe
  - High error rates (for signaling packets) compound the issues
- Limited efforts have been spent on inventing new enabling protocols, but a breakthrough is really possible !

A Network Scenario



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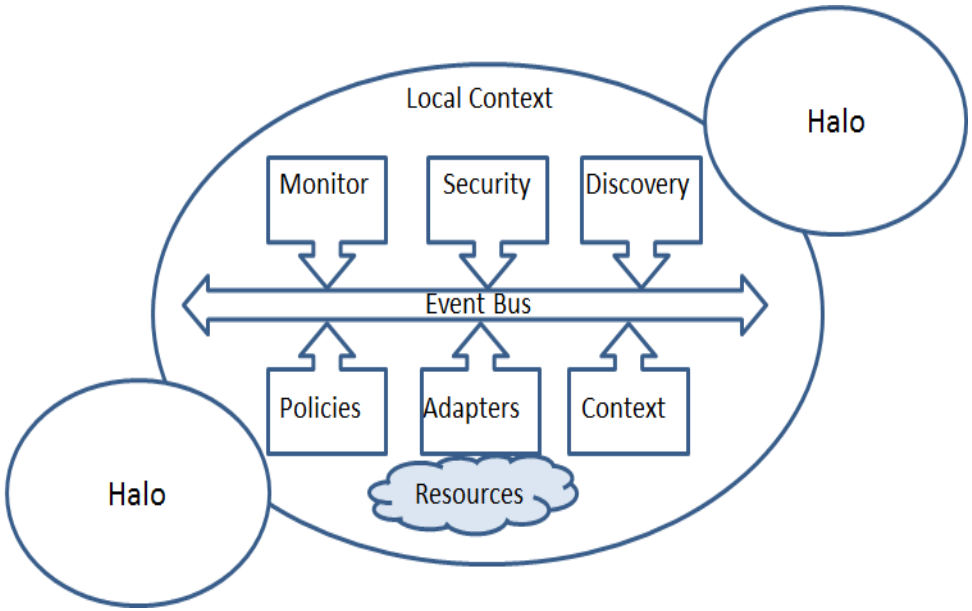
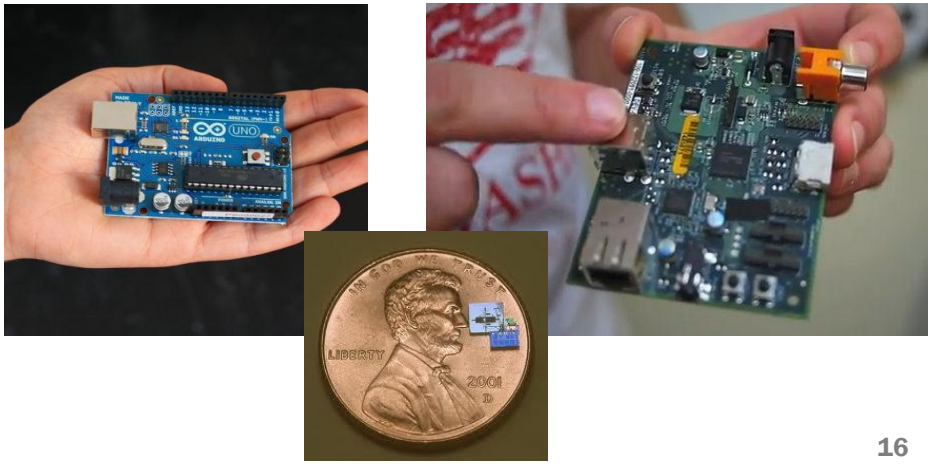
Halo node

- A halo node can be seen as a dynamic system whose states are time-evolving as events occur.
  - It is sensitive to the context variations and capable of reacting to self-adapt dynamically
- It is like a "self-managed cell" with a set of features, e.g.,
  - Discovery, Policies, Monitor, Security
- What is needed to build it ?
  - a smart phone (as Wi-Fi Hot Spot)
  - cheap, tiny PCs (e.g. Raspberry Pi)
  - microcontrollers (e.g. Arduino)
  - Sensors, actuators, etc.





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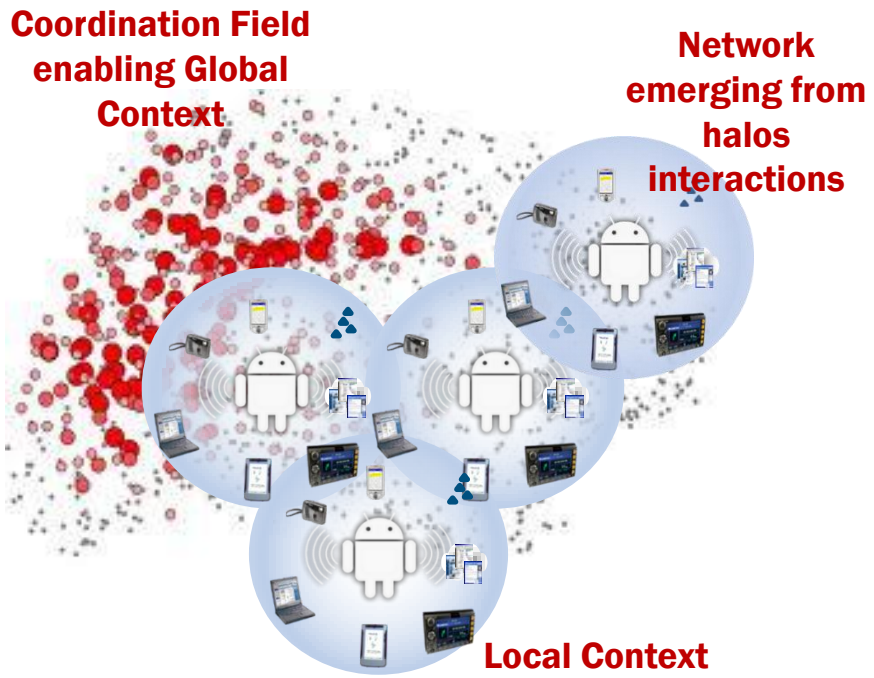
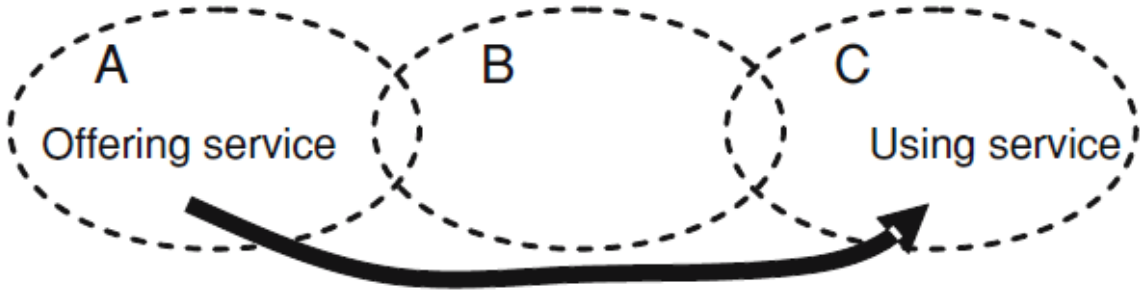
Halos Nets

- **Three biological behaviors:**
  - **Automatic**: in charge of fast pre-defined reactions designed by means of automatic control-loops;
  - **Autonomic**: local adaptation achieved by exploiting halos' learning capabilities;
  - **Globally Self-Organized**: in charge of diffusing local context information to orchestrate local reactions (activation-deactivation of rules) for reaching global goals (self-organization).
    - This layer exploits a sort of "controlled" reaction-diffusion process of context information.



Halos Nets



- **Different networks can learn each other's resources, functionalities and services and how optimally make use of them (i.e. symbiotic behaviors)**
  - **it will be possible indicating which networks can make use of the offered services**
  - **this will include support for relaying services, thereby offering services from other networks to their own neighbors**

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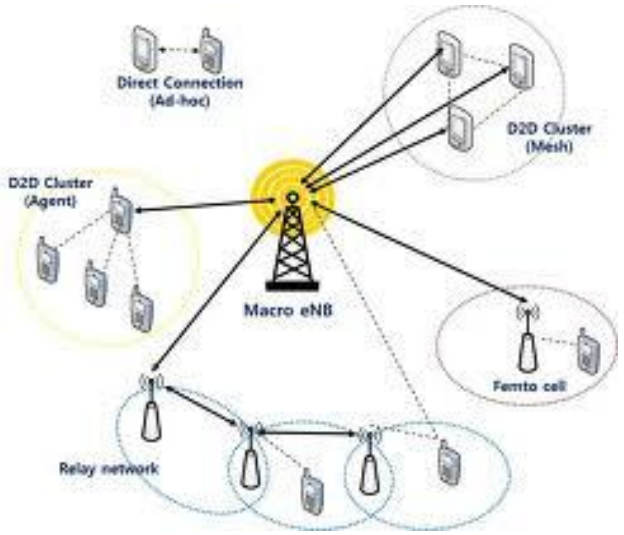
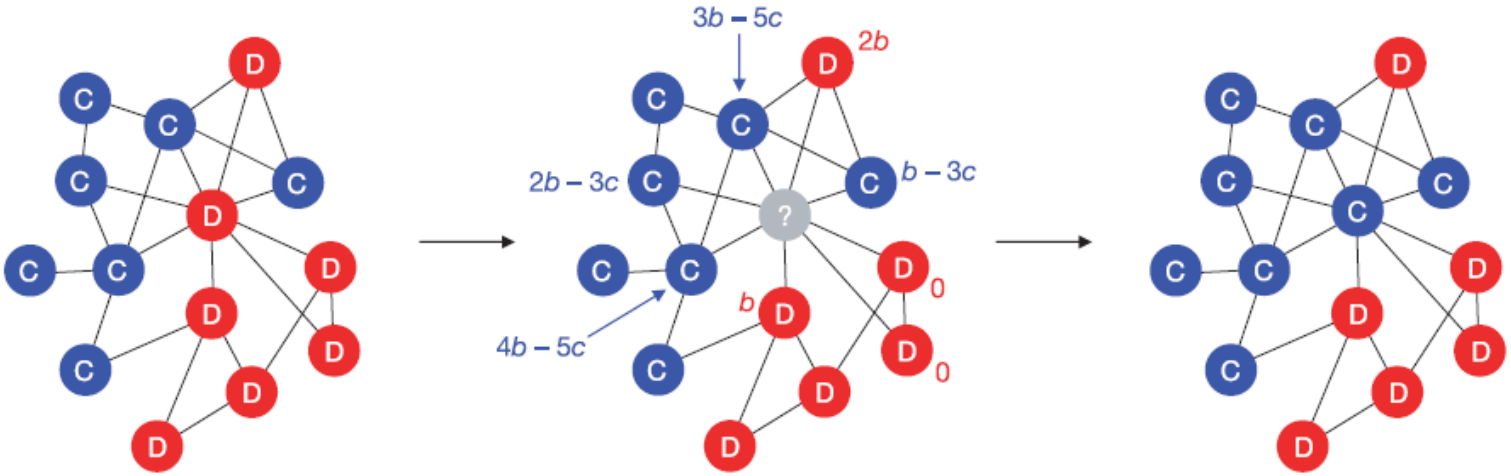
Cooperation is very important

- The maximum allowable distance for D2D communication is determined by the power level for each transmission.
- Goal: **best cooperation distance and sharing policy so that the number of active D2D links is maximized.**
  - The smaller the transmit power, the smaller the region in which a D2D communication creates interference.
  - On the other hand, a small transmit power might not be sufficient to reach a node.
  - Smaller power means smaller distance and hence smaller probability of collaboration opportunities.



Cooperation is very important

- **A fundamental aspect of all biological systems is cooperation.**
- **Natural selection favors cooperation, if the benefit of the altruistic act, b, divided by the cost, c, exceeds the average number of neighbors, k, which means b/c > k.**
- **It is necessary enforcing altruistic behaviors in Halos**



Hisashi Ohtsuki, “A simple rule for the evolution of cooperation on graphs and social networks”, Nature, Letters, Vol 441|25 May 2006|doi:10.1038/nature04605

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Blue Ocean Strategy

Red Ocean Strategy Focus on current customers	Blue Ocean Strategy Focus on noncustomers
• Compete in existing markets	• Create uncontested markets to serve
• Beat the competition	• Make the competition irrelevant
• Exploit existing demand	• Create and capture new demand
• Make the value-cost trade-off	• Break the value-cost trade-off
• Align the whole system of a firm's activities with its strategic choice of differentiation OR low cost	• Align the whole system of a firm's activities in pursuit of differentiation AND low cost

An Application scenario …

- **A City Operating System:** just like a Personal Computer OS, City OS gathers data from pervasive sensors and provide commands to related actuators. The sensors monitor everything in the City from large scale events such as traffic flows across the entire city, waste, logistics, energy use, water levels down to more local phenomena such as temperature and pollution.
- Eventually a myriad of vertical applications can be developed to run on the City OS to provide urban services

Conclusions

- Value is moving from the networks to the terminals
- Services are provided at the edge of the "network“
- Pursuing only a traditional approach, and adopting walled gardens, on the long run might be detrimental for Operators

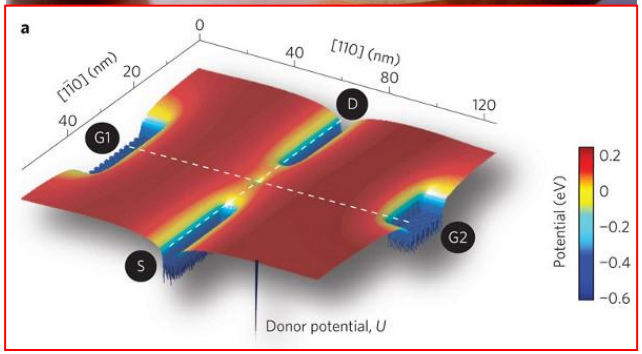
- IoT and IwT are excellent opportunities for Operators to become also “enablers of open environments” (Blue Ocean)
  - people are free to cross borders, to enter and exit from the environment, to interact and be the owners of their data.
  - any object is a gate to access new services

Conclusions

- Operators could also become IoT and IwT Providers by expanding their edge networks (e.g. through Halos Nets)
- Systems could be also deployed by Operators in conjunction with the Public Administrations
- Self-organization makes the life easier from a network management perspective (managing a plethora of small nodes and virtual entities is not possible!)
- Services and data will be virally delivered through multiple devices, machines, objects mostly by using local resources.
- A deeper and tighter coupling between the real and virtual worlds will accelerate science, business, society, and self-actualization.

This is only the beginning…

- Decreasing dimensions and costs of any portable device sensor, actuator…
- Printed electronics circuitry paving the way for digital clothing, flexible displays and signage, lighter e-book readers, solar cells, sensors and “smart” everyday objects !
- Nano electronics…now reaching up to single atom transistor (1)



(1) http://www.engadget.com/2012/02/21/single-atom-transistors-point-to-the-future-of-quantum-computers/

Arrivederci !

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