IP in Wireless Sensor Networks

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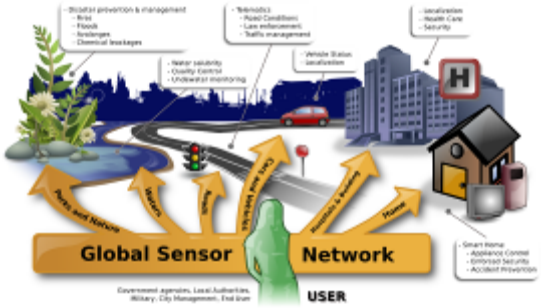
The number of applications for Sensor Networks is endless

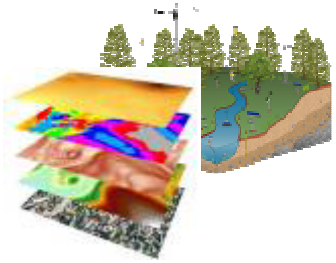
Defense

Predictive maintenance

Energy Saving (I2E)

Improve Productivity





New Knowledge

Intelligent Building

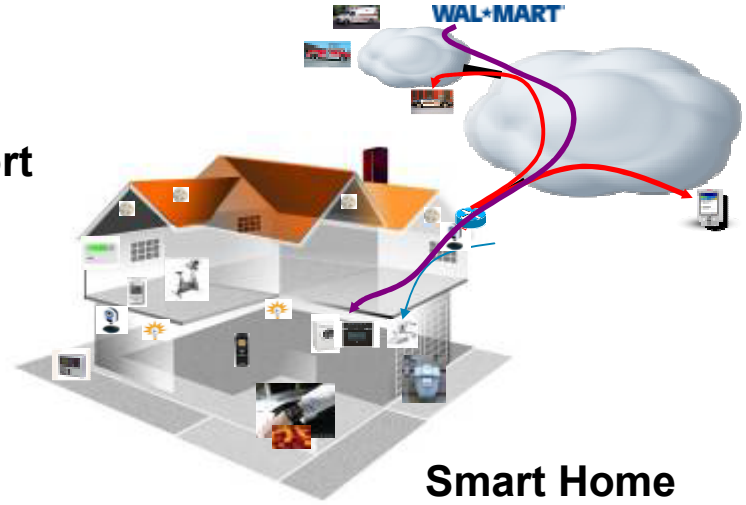
Agricultural

Smart Cities

Industrial Automation

High-Confidence Transport and assets tracking

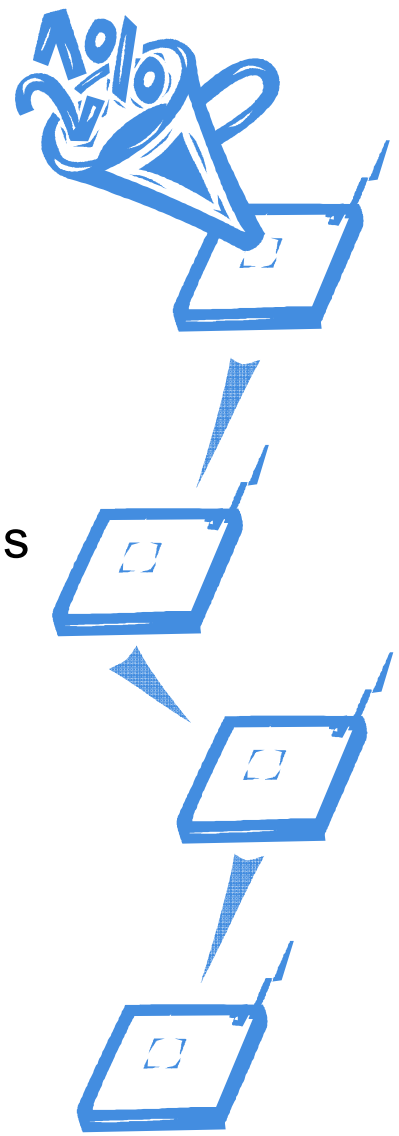
Healthcare



Smart Home

Wireless Sensor Networks

- Scaling up M2M (lower cost, numerous devices)
- Limited capabilities to scavenge and store power
- Limited CPU and memory
- Expensive listen and send - long deep sleep periods
- Ability to withstand harsh environmental conditions
- Autonomous and reliable (self forming self healing)
- Highly dynamic network topologies
- Heterogeneity of nodes – new types of nodes
- Unattended operation – M2M closed loop



Why IP for Sensor Networks ?

New applications pretty much every day … but …

The number of ***proprietary*** solutions has ***exploded***: Z-Wave, Xmesh, SmartMesh/TSMP, … at many layers (physical, MAC, L3) and most chip vendor claim to be compatible with their own ***standard***

- Many non-interoperable "solutions" addressing specific problems ("*My application is specific" syndrome*)
  - Different **Architectures**,
  - Different **Protocols**

=> Deployments are limited in **scope** *and* **scale,**

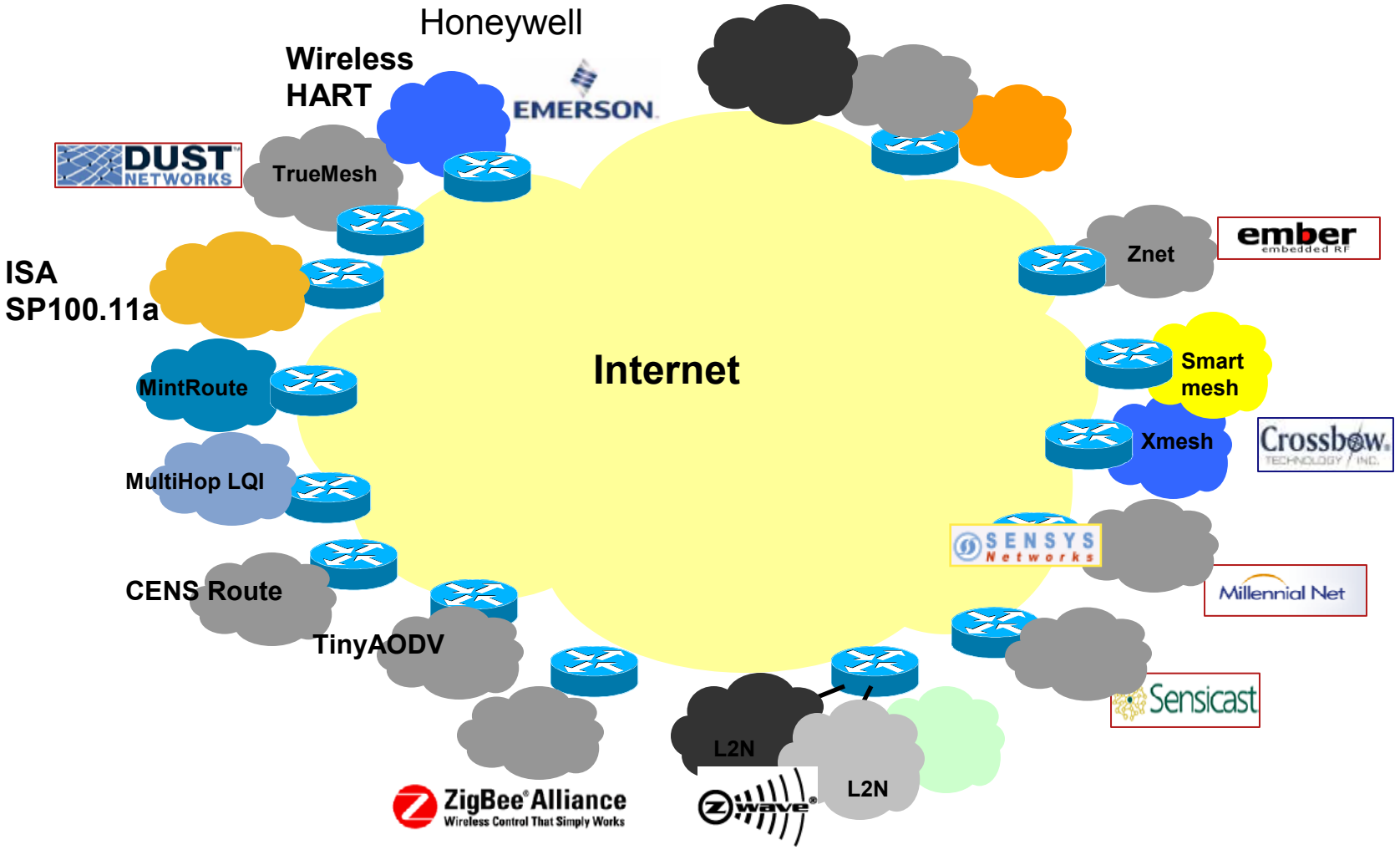
The Internet of Things - Security

Connecting Smart Objects, sensor, actuators using IP

 an open access to the Internet !

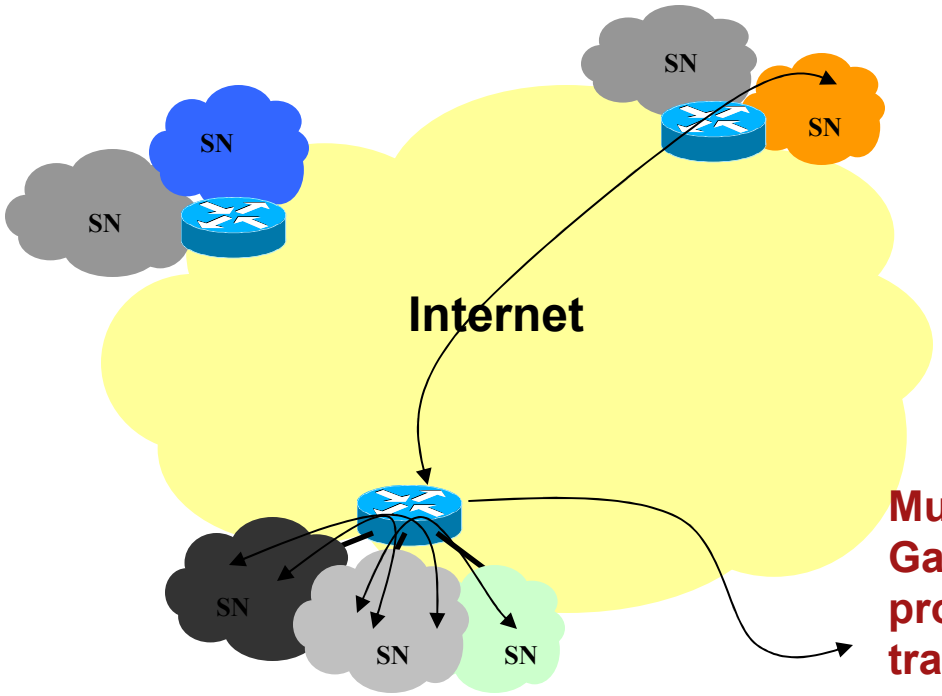
- Some Sensor Nets will require (controlled) access from the Internet, others will stay “Isolated”
- 802.15.4 provides built-in AES128 encryption which is enabled beneath IP, much like WPA on 802.11.
- Proprietary protocol  increased security, and many of them make use of less non state of the art security mechanisms

So far … WAS (Wait And See) - A trend that we can reverse …



Most promoters of non-IP solutions have understood that IP was a MUST: they call this “IP convergence”: **A protocol translation gateway ! Or Tunneling …**

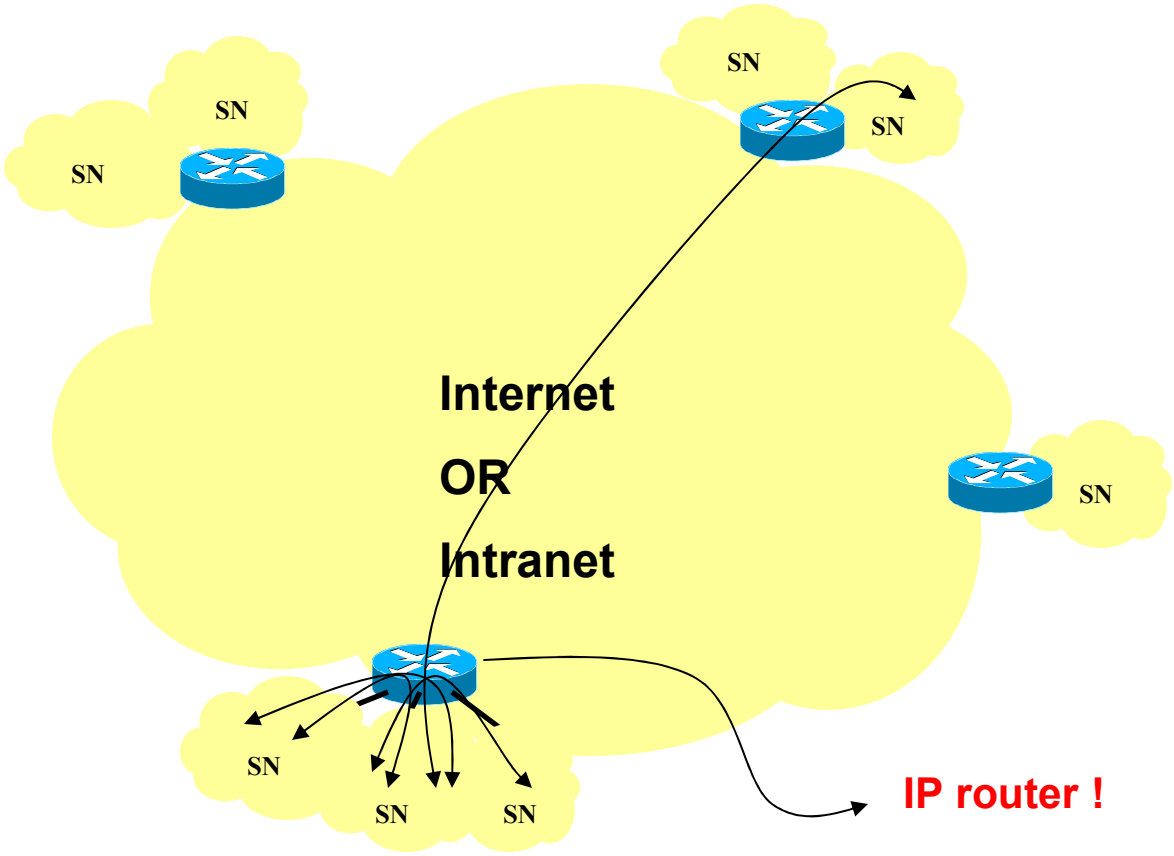
Protocol Translation Gateways – Well known issues



Haven't we learnt from the past ? Remember SNA (DLSw), IPX, Vines, …

- **Complex to manage, expensive and non scalable !**
- **Lack of end to end routing consistency, Multi-topology routing, management, security, …**
- Migration will be challenging and even just not be possible for Sensor Networks after too much time

Or … IP end to end



Which does not mean a single flat domain of course

A FUNDAMENTAL requirement

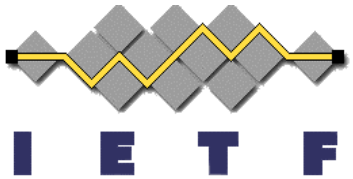
- **Sensor networks will be made of a number of links: 802.15.4, Low Power 802.11, Low power Bluetooth but also wired links**
- **The solution MUST support a variety of links (IP) while understanding the links characteristics (use of abstraction layer).**

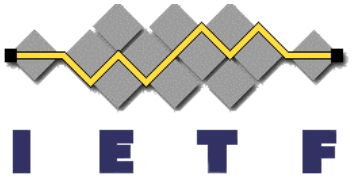
A few key design principles of the Internet

- ***What ?*** **A Layered architecture => flexible,**
- ***Where ?*** **The End to End design principle,**
- ***How ?*** **Separation of the networks from the services: IP indifferent to PHY and applications,**
- ***Why ?*** **The Internet as a platform for innovation. No central gatekeeper exerting control over the Internet.**

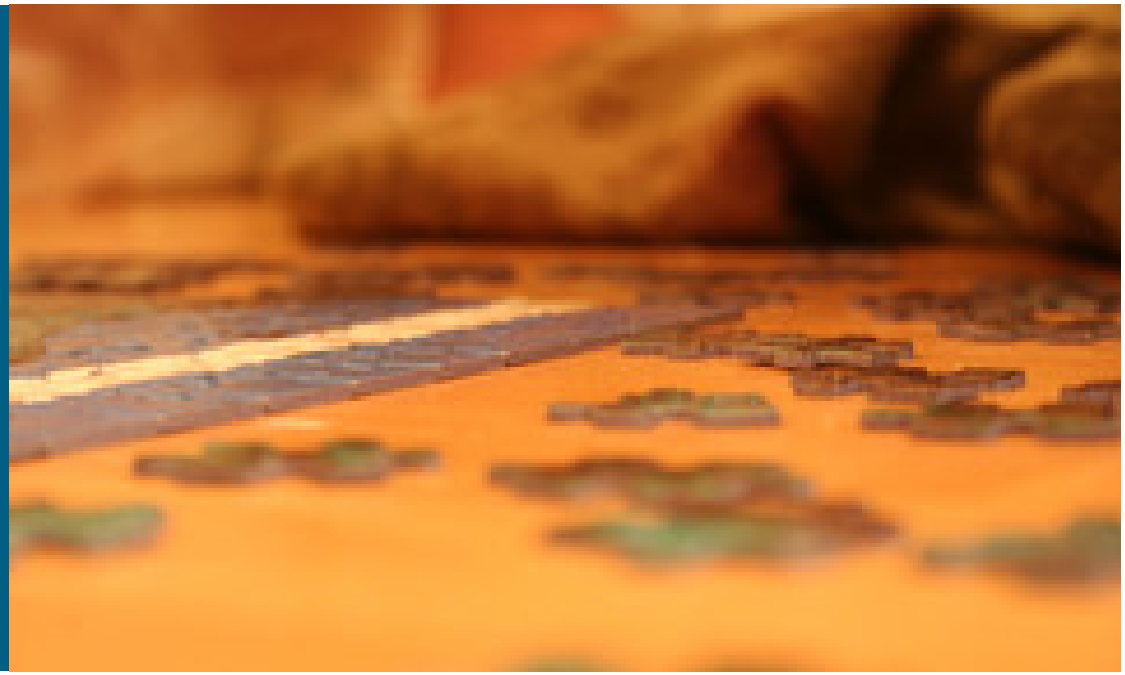
Source: Prepared statement of Vint Cerf - Feb '07

The IP protocol suite is based on open standard designed for interoperability, extensibility … as opposed to seeking for local optimums





Work at the IETF

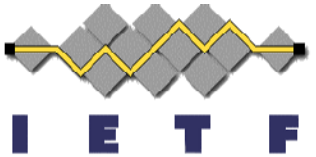


Can we make The Internet of Things a reality? YES ! With little effort …

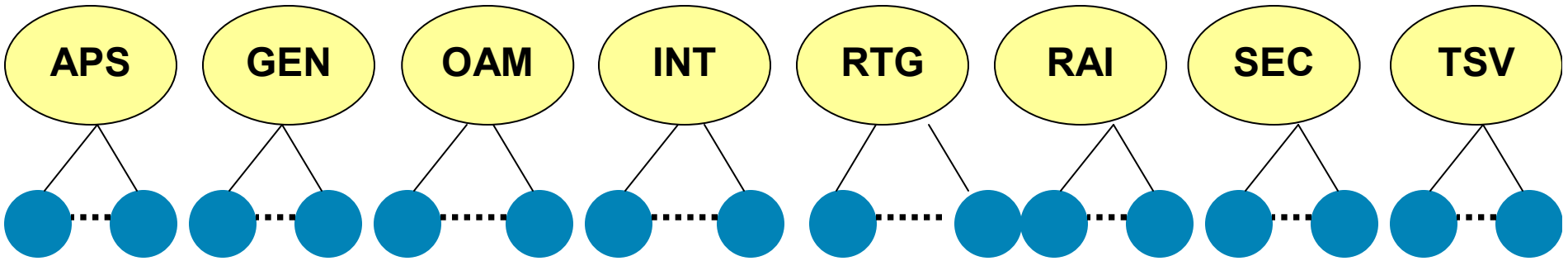
- Do not try to find a solution to all potential problems: **reduce the problem scope**
- Adapt or reuse existing protocols … do not reinvent the wheel ! : DHCP-like, SNMP, ….
- Design new IP-based protocols **when** needed:

  Example ? Routing … (IETF ROLL WG)
- Preserve the fundamental openness of IP
- IP is ubiquitous and Sensors are everywhere … Good match.

The Internet Engineering Task Force

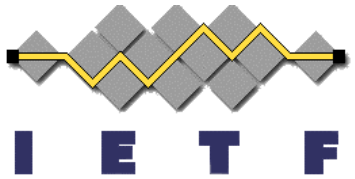


- IETF formed in 1986,
- Not considered as important for some time :-)
- Not government approved :-)
- Involving people not companies
- Motto: *"**We reject kings, presidents and voting. We believe in rough consensus and running code**"* Dave Clark (1992)
- Organized in areas made of WGs,



- Roughly 120 WGs
- Long term problem handled by the IRTF

Sensor related IETF activities



- 6LoWPAN

  IPv6 over Low Power Personal Area Networks

- MANET and ROLL

  6LoWPAN Mesh Routing Requirements defines the problem statement, design goals, and requirements for mesh routing in low-power wireless personal area networks (LoWPANs).

- 6MAN, v6Ops

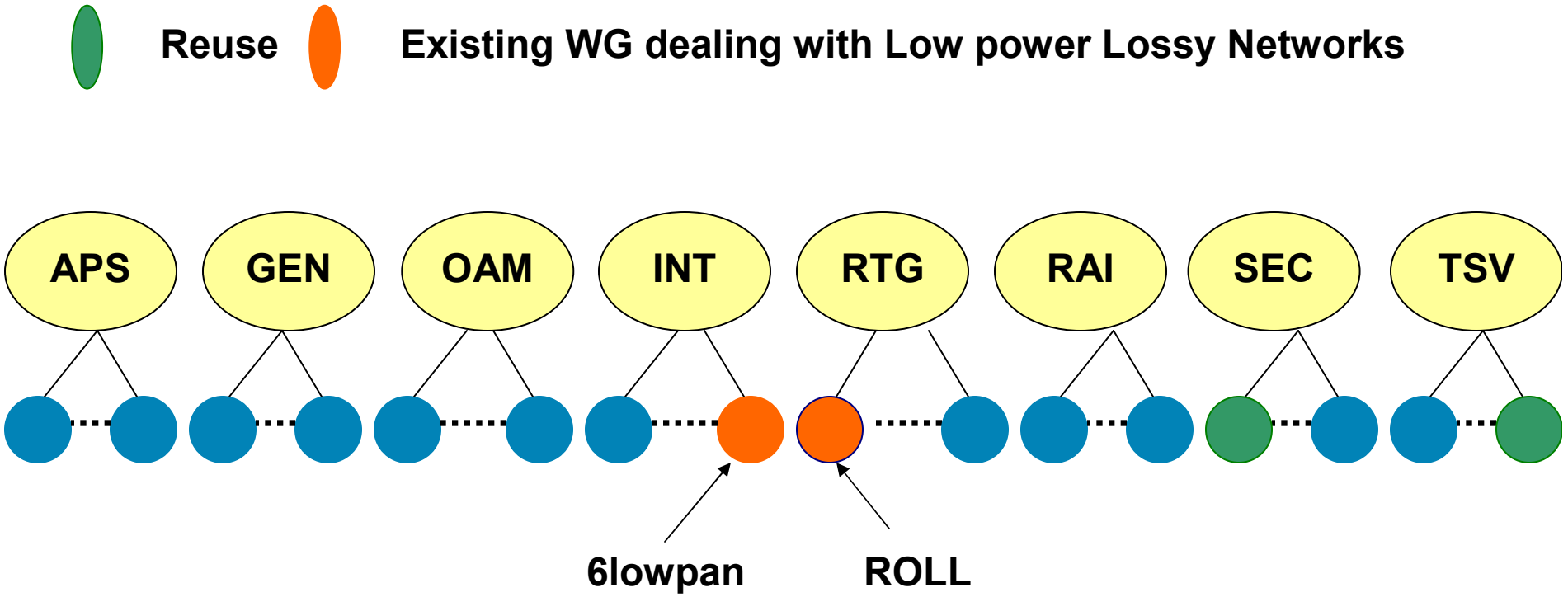
  Minimum IPv6 stack for embedded devices

- Mobopts, Mobility Optimizations:

  LowPan Mobility Requirements-Goals discusses a few scenarios of mobility in LowPan network and states mobility requirements and goals for LowPan networks. The draft was proposed to move from Mobopts to 6LoWPAN WG.

IETF Update

- Reuse whenever possible, Invent where needed



6LowPAN Overview, Assumptions, Problem Statement, and Goals RFC 4919

IEEE 802.15.4 Networks, characterized by:

- Significantly more devices than current networks
- Severely limited code and ram space

  highly desirable to fit the required code--MAC, IP and anything else needed to execute the embedded application-- in, for example, 32K of flash memory, using 8-bit microprocessors
- Unobtrusive but very different user interface for configuration

  using gestures or interactions involving the physical world
- Robustness and simplicity in routing or network fabric
- More in RFC 4919
- 802.15.4 a, b, 2003, 2006, and maybe wibree

  Extensible to LP WIFI by removing fragmentation

Other 6LoWPAN Documents

- **Adaptation layer for interoperability and packet formats**

  An adaptation mechanism to allow interoperability between IPv6 domain and the IEEE802.15.4 can best be viewed as a layer problem. Identifying the functionality of this layer and defining newer packet formats, if needed, is an enticing research area.

  RFC 4944 proposes an adaptation layer that carries out the functionality of the adaptation layer. A new draft enables more compression.

  6lowpan architecture describes the architecture incorporating IEEE 802.15.4 subnetworks

- **Addressing management mechanisms**

  The management of addresses for devices that communicate across the two dissimilar domains of IPv6 and IEEE802.15.4 is cumbersome, if not exhaustingly complex. A mechanism has been put forth in the RFC 4944.

- **Routing considerations and protocols for mesh topologies in 6lowpans**

  Routing per se is a two phased problem that is being considered for the 6lowpan. Mesh routing in the personal area network (PAN) space. And the routability of packets to/from the IPv6 domain from/to the PAN domain.

  It is expected that ROLL WG will define routing for LoWPANs.

- **Device and service discovery**

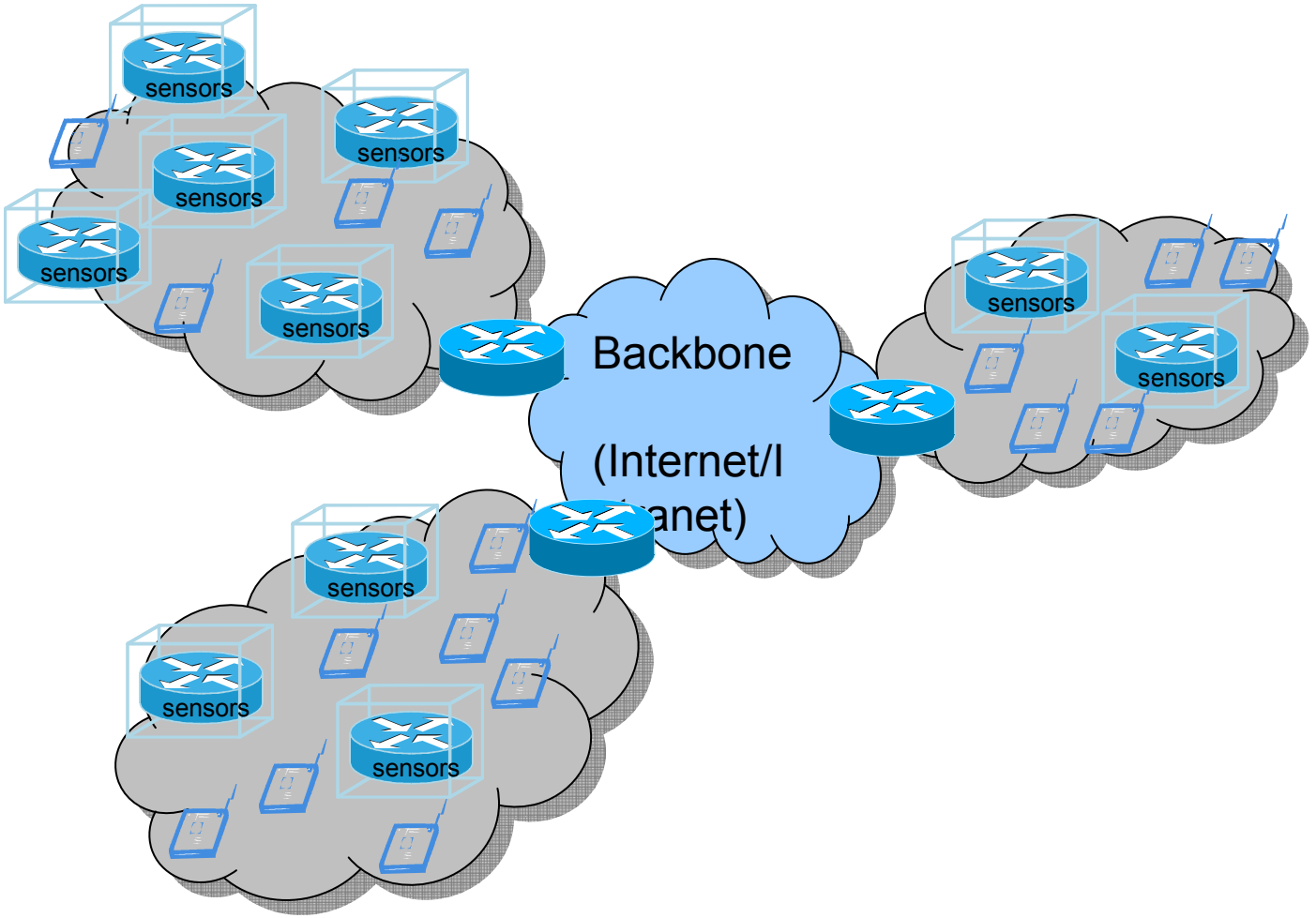
  Since the devices in 6lowpan may result into ad hoc formation of networks, current state of the neighboring devices, peer devices, and the services hosted by such devices may be required to be known.

  6lowpan neighbour discovery extensions is an internet draft proposed as a contribution in this area. Backbone Router proposes a white board model associated to proxy ND over the backbone.

- **Miscellaneous**

  Simple fragment recovery is proposed to avoid classical fragmentations issues.

ROLL: defining the routing solution within the LLN (Low power and Lossy Network)



Routing Over Low power and Lossy Link (ROLL) WG

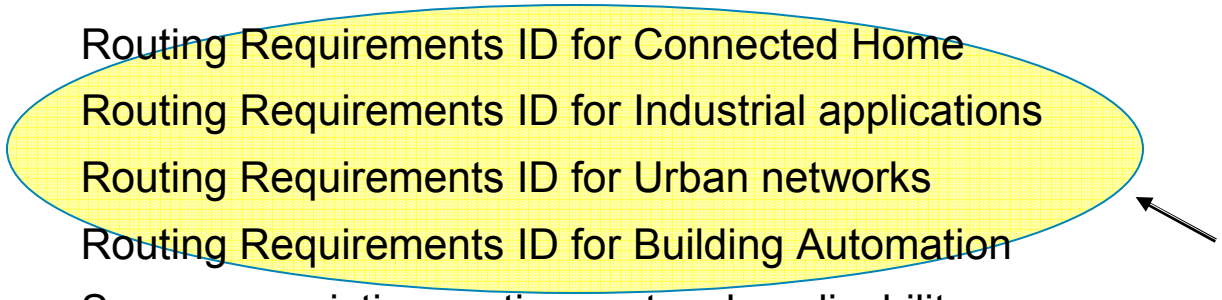
- Working Group Formed in Jan 2008

  http://www.ietf.org/html.charters/roll-charter.html

  Co-chairs: JP Vasseur (Cisco), David Culler (Arch Rock)

- Work Items

  Routing Requirements ID for Connected Home
  Routing Requirements ID for Industrial applications
  Routing Requirements ID for Urban networks
  Routing Requirements ID for Building Automation
  Survey on existing routing protocol applicability
  Routing metrics for LLNs
  Routing for LLNs Architecture document



We did limit the scope !

- Active work with a good variety of participants
- Already three WG documents as of May 2008.

ISA100.11a

IPv6-based Low-power
Wireless Personal Area Networks

Industrial monitoring and control

- Today:
  - Competing standards,
  - Mostly wired fieldbuses
- Ethernet/IP presence
  - CIP / EtherNet
  - Modbus/TCP
  - Foundation Fieldbus HSE
  - PROFInet
  - Invensys/Foxboro FOXnet
- Wireless coming up
  - WiHART
  - One-wireless
  - ISA100.11a

ISA

- **Instrumentation, Systems, and Automation Society** is a non-profit technical society for engineers, technicians, businessmen, educators and students, who work, study or are interested in industrial automation.
- It was originally known as the **Instrument Society of America**.
- ISA provides leadership and education in the instrumentation and automation industries, assisting engineers, technicians, and research scientists, as well as many others, in keeping pace with the rapidly changing industry.

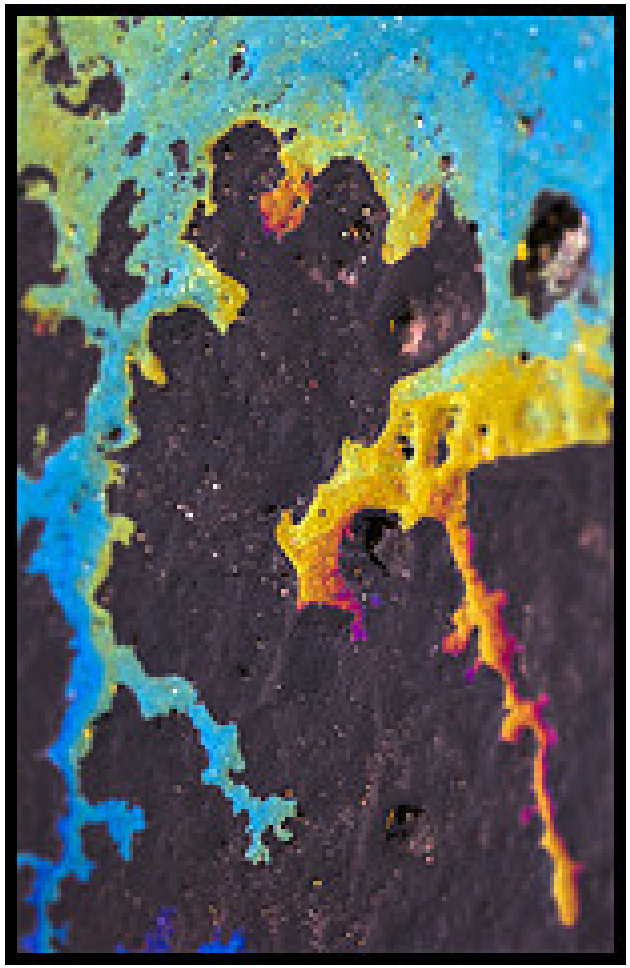
ISA100.11a Working Group Charter

This project addresses:

- **low energy consumption devices, with the ability to scale to address large installations**
- **wireless infrastructure, interfaces to legacy infrastructure and applications, security, and network management requirements in a functionally scalable manner**
- **robustness in the presence of interference found in harsh industrial environments and with legacy systems**
- **coexistence with other wireless devices anticipated in the industrial work space**
- **interoperability of ISA100 devices**

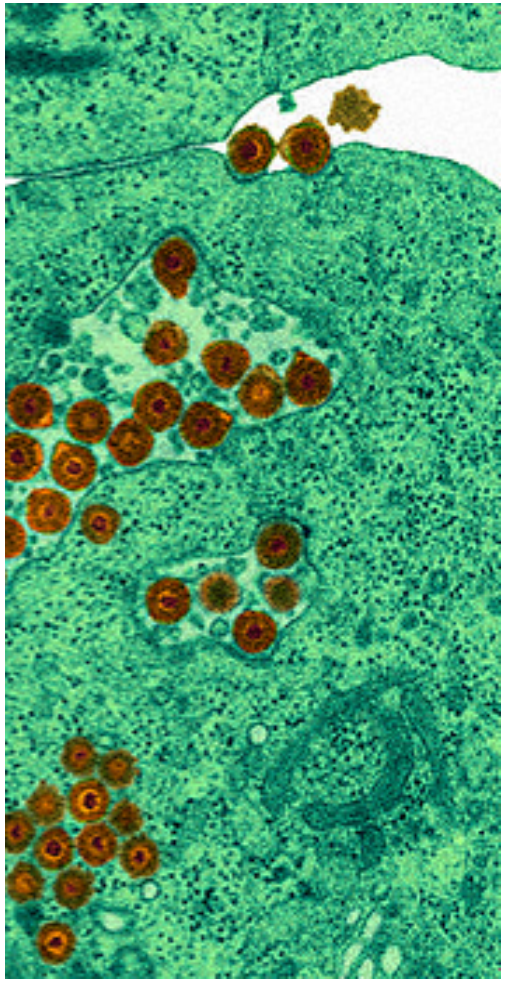
ISA100.11a key features

- Hybrid FHSS DSSS
  - reused from TSMP/WiHART
  - Interference mitigation
- IPv6 and backbone
  - Scalability, Scope
  - Open protocols, COTS
  - Network Convergence
- Extensible
  - New PHYs (802.11LP, 802.15.4a CSS)
  - New app layers (WiHART)



ISA100.11a, IP technology and IETF

- ISA 100.11a endorsed 6LoWPAN
  - IPv6 packets but not stack (ND, ICMP)
  - And the transit link is not covered yet
  - Really need draft-hui for better compression
- Backbone Router draft @ 6LoWPAN
  - Proposing an IPv6 based best practice
  - To promote full IPv6 in ISA100.11a
  - And WSN in general by contagion
  - Have chairs and partners support
- Also I-D on fragment recovery
  - 6LowPAN sends up to 25 fragments
  - Over multihop lossy radio
  - => Need Flow Control and recovery



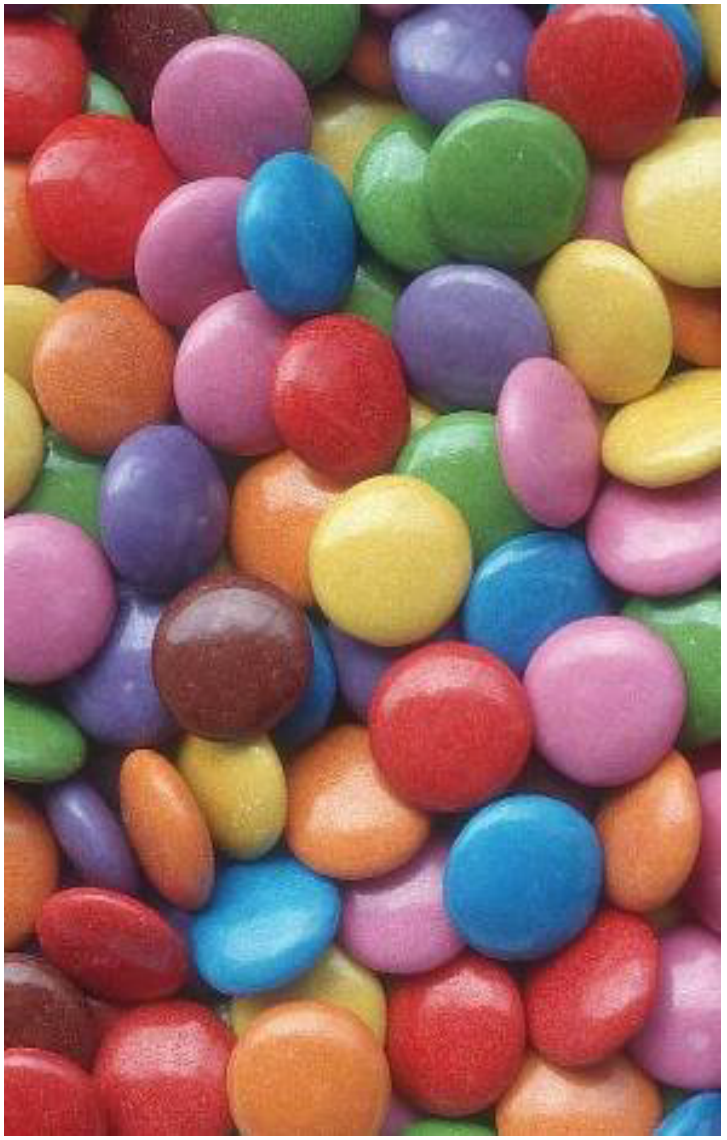
Vision

Building automation

- Today:
  - Highly fragmented market
  - Limited to no IP/wireless
  - Dominated by BACNet (20%MS)
- Potential for:
  - open standards
  - ISA100.11a extension
- Applications
  - Energy savings
  - Regulation
  - Security

Smart cities

- Today:
  - Slowing development of mesh networks
  - Few applications (surveillance, muni info)
- Potential for:
  - WIFI/WIMAX integrated Mesh
  - ISA100.11a
  - IPv6 networking
- Applications
  - Energy/Water savings
  - Water leak detection
  - Traffic Regulation
  - Physical Security
  - Air quality monitoring

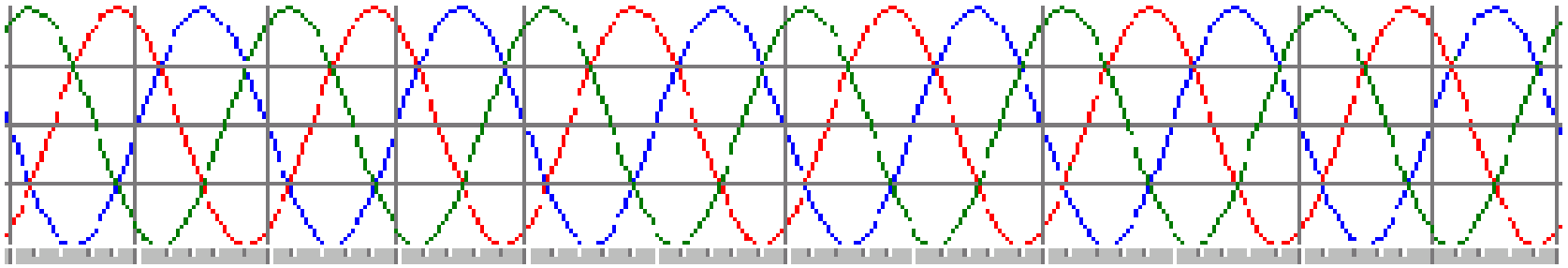


Home Automation

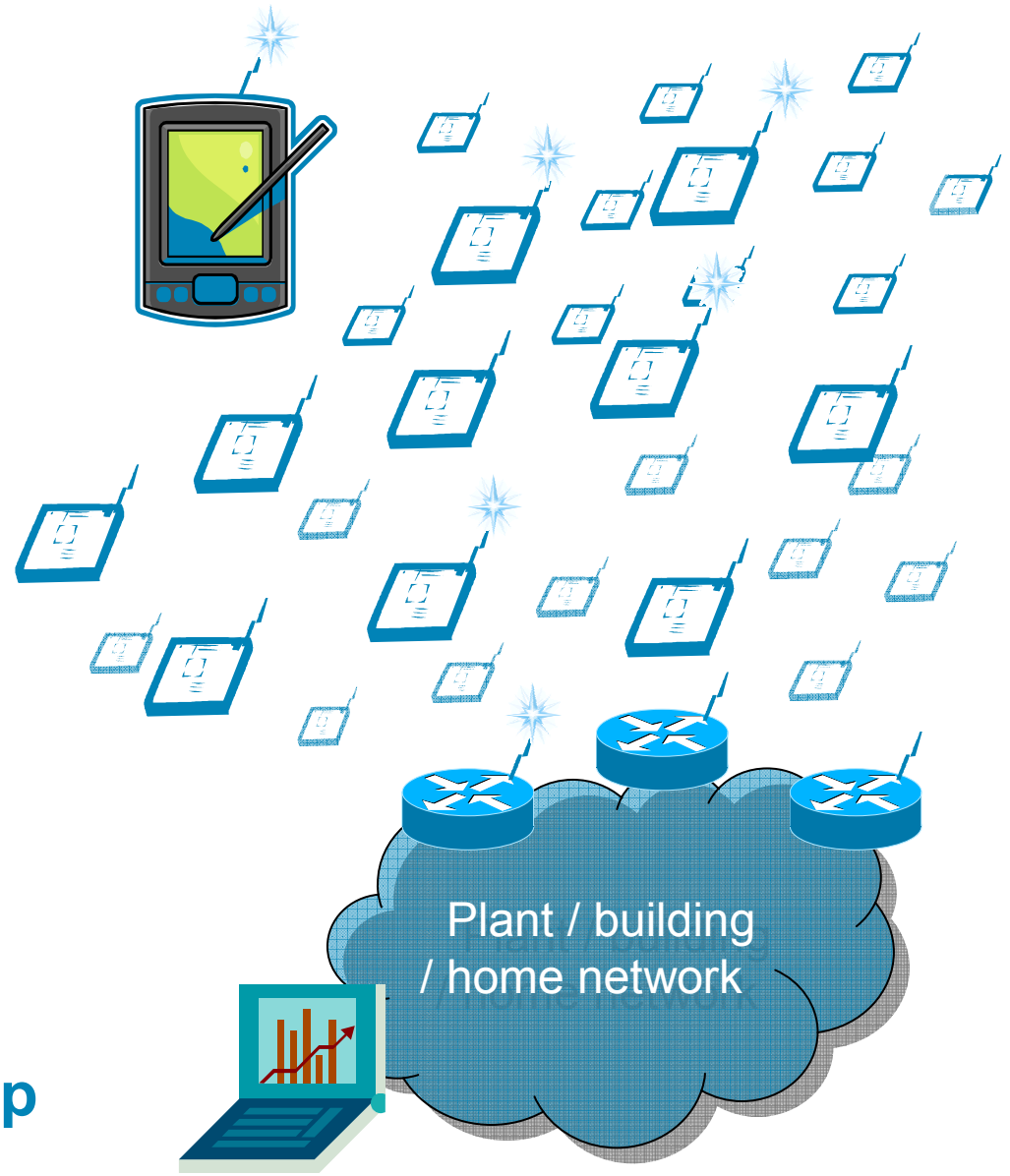
- Today:
  - Lot of wires
  - Some powerline (homeplu
  - ISP presence (FT)
- Potential for:
  - WIFI Low Power 802.15.4
  - IP home networking
- Applications
  - Energy/Water savings
  - Home security
  - Home Safety
  - Remote healthcare
  - Telemetry
  - Air quality monitoring

Power grid

- Emerging PLC/BPL access technology
- Low frequency (<kHz) applications for Utility
  - Automatic meter reading
  - Load control



- Converged network
- Scalable Plug & Play
- High Availability
- VLANs and VRF
- Open Standards



⇒ lower, scalable and shared cost of ownership

IP to the Sensors

- New services and applications
  - M2M, remote management
- New Markets
  - Process Control for factories
  - Control and Automation
    - for home, building, cities
- Larger Core Market
  - Open standards to the sensor
  - ⇒ Lower cost
    - ⇒ More connected devices and new applications
      - ⇒ A wider Internet
- Shaping the future
  - Internet of things

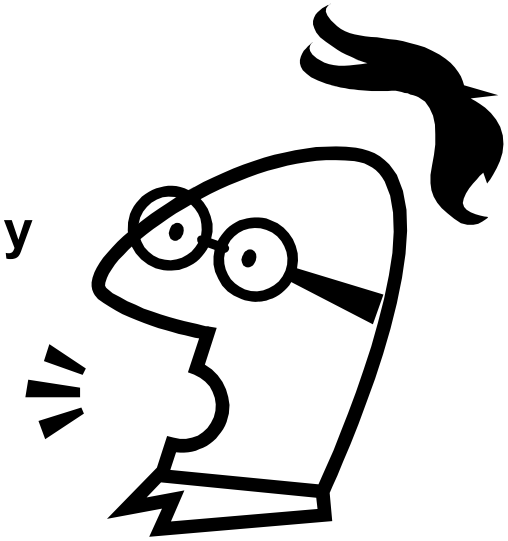
Think of VoIP as a model…

…but for a great many…

…of tiny devices, everywhere.

The golden path

- Vision
  - Sensors and actuators using Internet **technology**
  - That's Billions of devices in the next 10 years
  - Enabling new services and applications
- Steps
  - IP for automation open standards (ISA100.11a)
  - IP for LLN (Low power and lossy networks) (6LoWPAN and ROLL)
  - Apply standards where needed (home, building, power grid)



Resources

Useful links

- Cisco web page on secure wireless plant
- Cisco/Emerson Joint RF Co-existence white paper
- Ethernet to the factory