The Internet of Thing

Internet Area Meeting

IETF 77 – Anaheim
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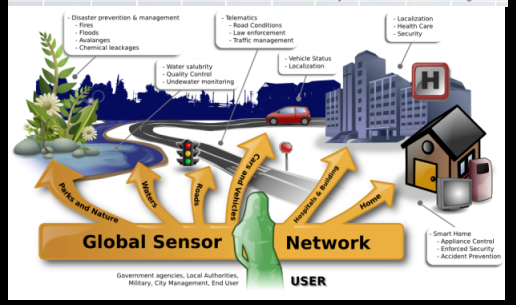
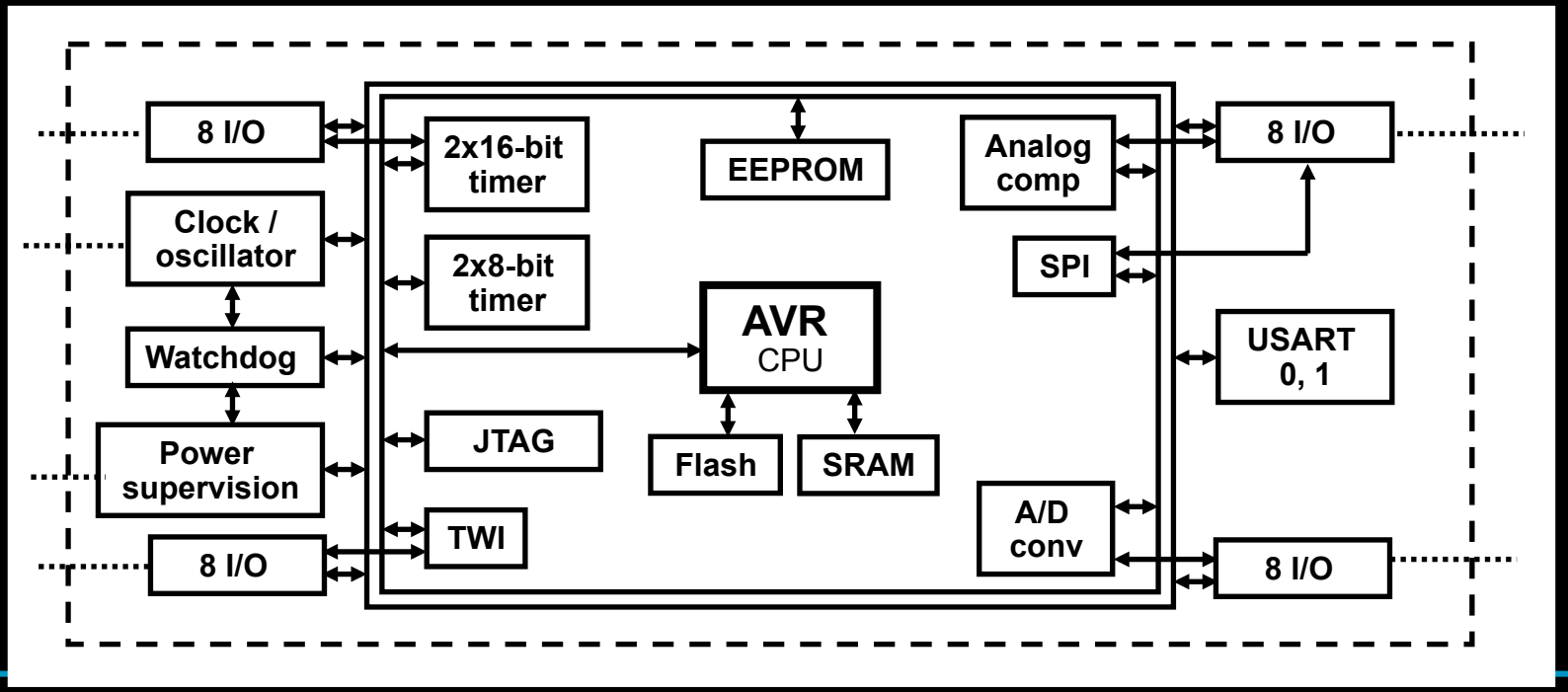


What is a "thing" or a Smart Object?

- An intelligent tag (RFID),
- A sensor: device that measures a physical quantity and converts it to a analog or digital signal: power consumption and quality, vibration of an engine, pollution, temperature, CO, motion detection, temperature, …
- An Actuator: device that controls a set of equipment (e.g. control and/or modulates the flow of a gas or liquid, control electricity distribution, perform a mechanical operation)
- Any combination of the above features to form a more complex entity
- In MOST cases, an unattended (constrained) devices communicating with others objects in a potentially very large scale environment

Just one example of new micro-controller: Atmel Atmega1284P

- 20 MIPS at 20MHz
- 128KB Flash, 16KB SRAM, 4KB EEPROM
- 6 sleep modes: 0.1µA -> 200 µA
- 32 programmable I/Os



The Internet of Things ?

- Need to step back on terminology …

  Sensor networks,

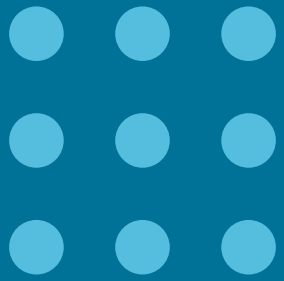
  Low power and Lossy Networks (LLN) ?

  6LoWPAN

  Internet of Things,

  Smart Object Networks

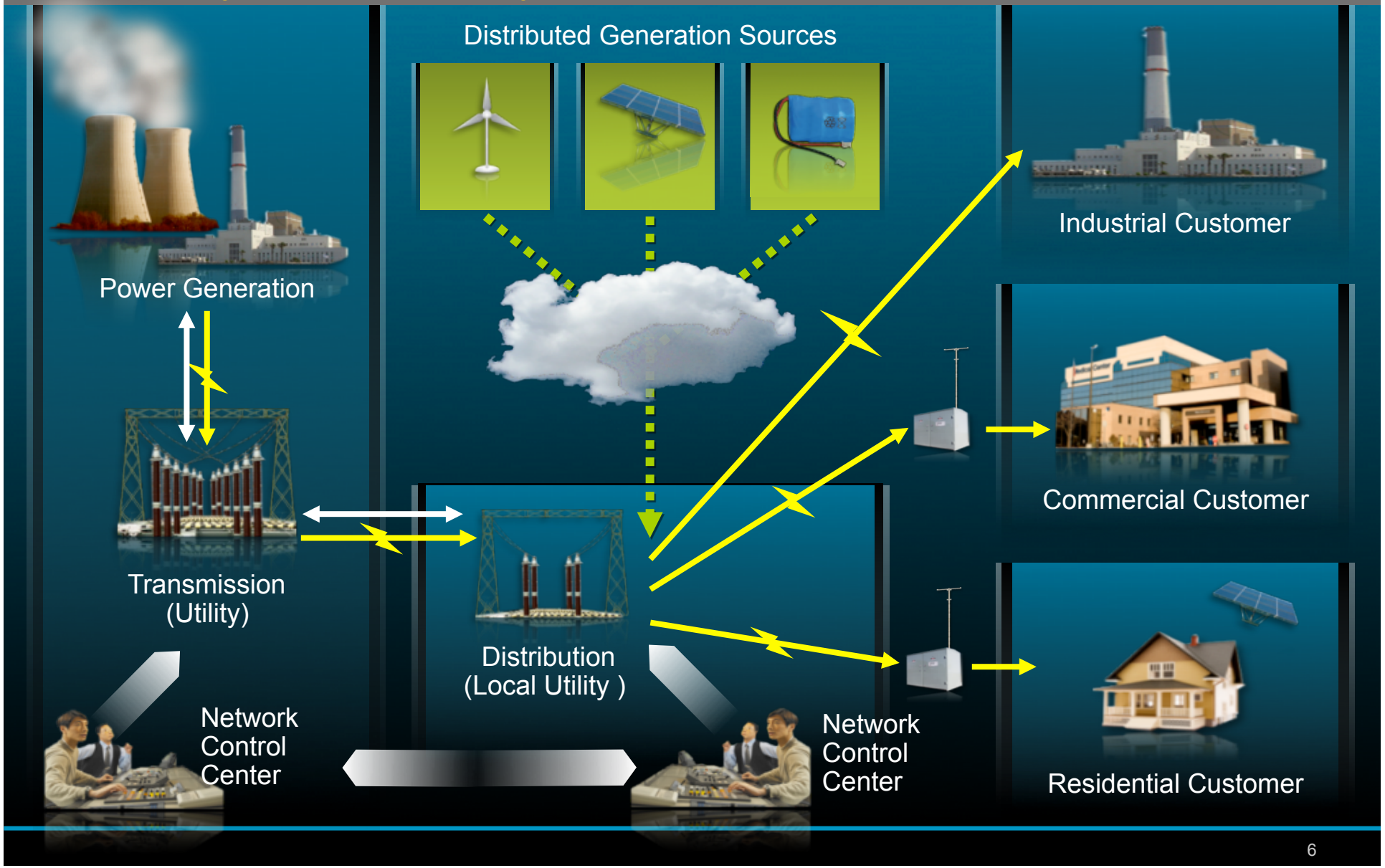
- No, The Internet of Things is not a *cool* thing: critical applications are ***there***
- ***We cannot miss that major transition***



Killer applications

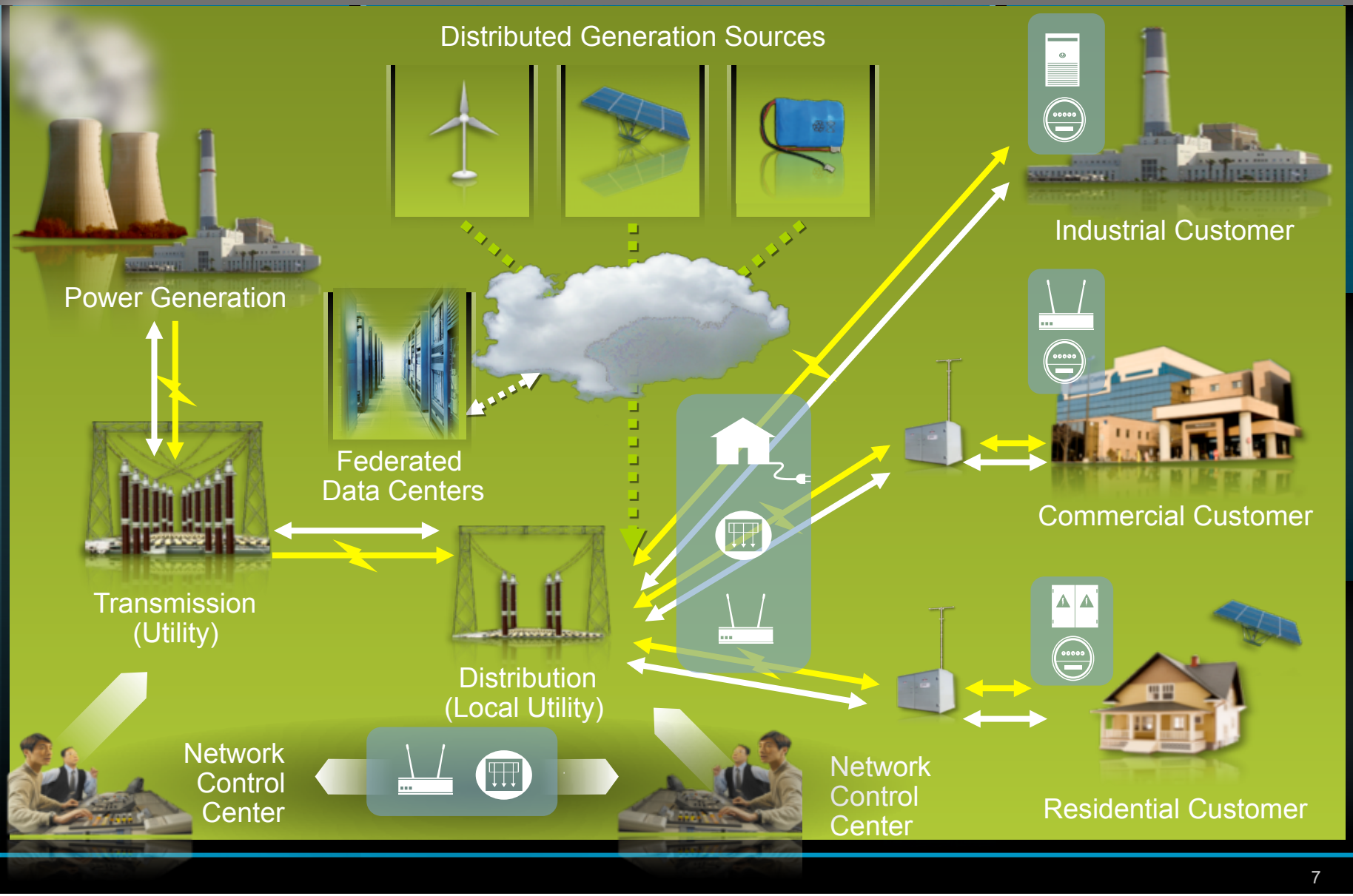
Power Management

Today's Electrical System

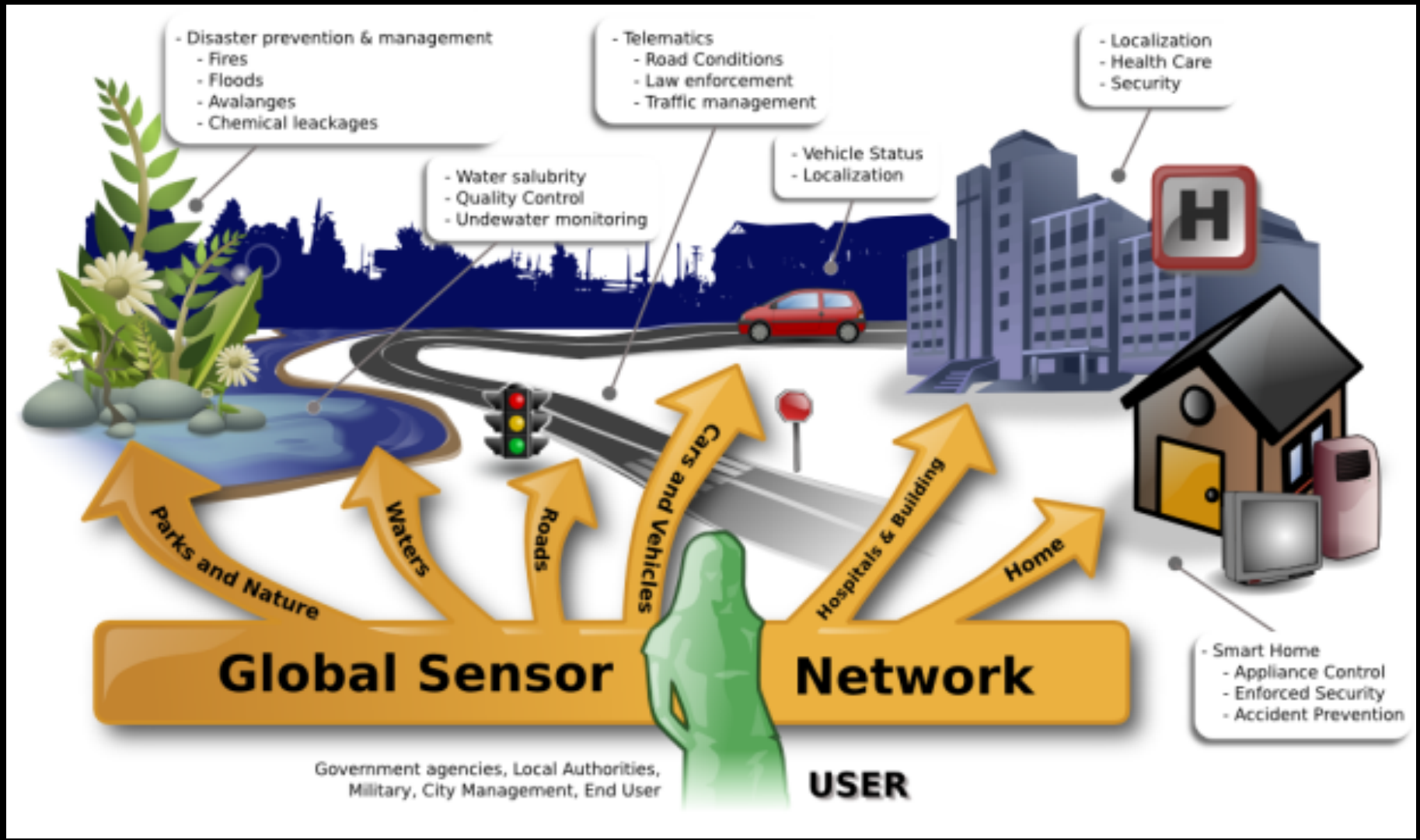


Power Management

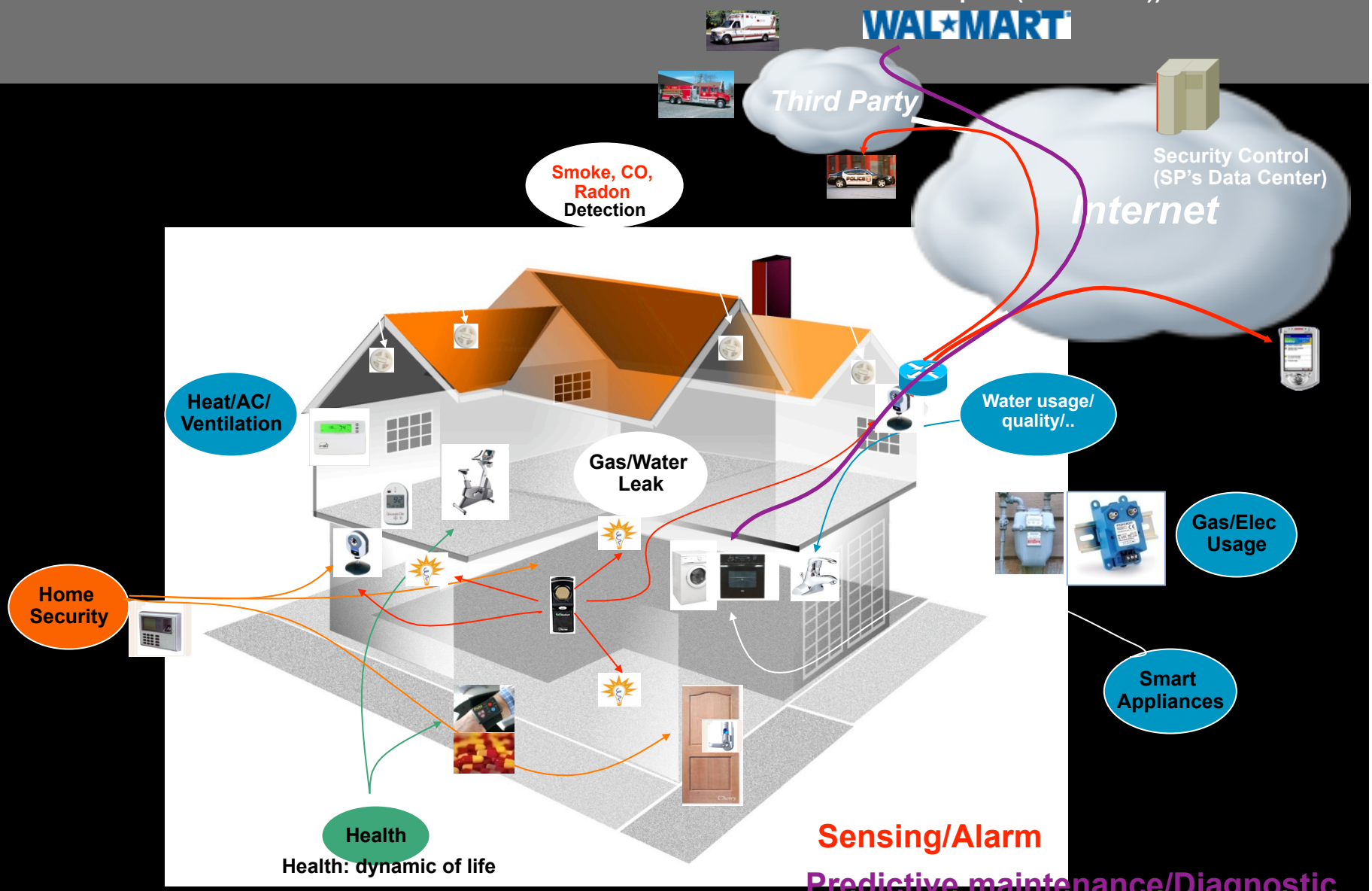
Smart Grid

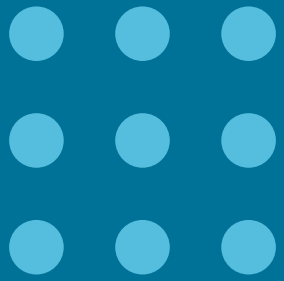


Smart+Connected Communities



Connected Home





Some *important* “historical background”

Great interest from the research community

- Usually referred to as Sensor Networks or even Wireless Sensor Networks (WSN)
- *Why so much interest ?*

  Potentially many applications

  Complex areas, lots of NP complete problem ☺

  Novel …
- Most focus on algorithms
- Limited interest in ***protocols*** and ***architecture***
- Many interesting and valuable contributions over the past decade

Sensors and Actuators have been used in the industry for a few decades

- Mostly RS485 wired sensors/actuators
- ***Very much proprietary architecture for specific application***
- And with in several cases… layer collapse, … with the belief that this would make the stack more optimized ☹ trade-off flexibility for (potential) compactness

One of the major issues 2-3 years ago …

- High number of ***proprietary or semi-closed*** solutions
- Many non-interoperable "solutions" addressing specific problems ("*My application is specific" syndrome*)
  - Different **Architectures**,
  - Different **Protocols**

… with … The usual "*My environment has specific requirements and requires a specific solution*" syndrome => Local versus global optimum !!

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

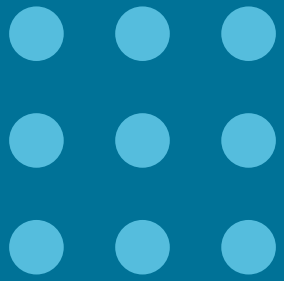
There are also a number of standardized non-IP protocols, …

Why not IP ?

A Long list of myths and/or misunderstandings …

- **IP is way too greedy and heavyweight for constrained devices …**
- **IP is unsecure**
- **Proprietary means secure …**
- **IP not optimized for these constrained environments**
- **IP smart object networks are opened to anyone in the Internet**

Just wrong …



Why IP for Smart Objects Networks?

IP end to end for "The Internet of Things" is a MUST …

Why not using protocol translation gateways ?

- Very different situation than 15 years ago with SNA, IPX, … (few exception but we have a strategy)
- Protocol translation gateways is the wrong approach for the "Internet of Things":
  - Expensive and difficult to manage (CAPEX and OPEX)
  - Number of technical issues: end to end lack of QoS, routing and fast recovery consistency
  - Force down the path of the least common denominator
  - Clearly not an enabler for innovation
  - Different scale !
  - Security holes …

So … which protocol and architecture ?

- The architecture and protocol MUST have a specific properties:
- Based on **open standards**: for interoperability, cost reduction and innovation … almost all proprietary protocols died …
- **Flexibility** in many dimensions:
  - Support a wide range of media
  - Support a wide range of devices
- **Always favor global than local optimum**: all protocols solving very specific issues never survived ☹ - We live in a fast changing world
- Highly secure
- **Plug & Play**
- **Scalable**

A plethora of emerging new low power media for Smart Object

- Things are fast changing since the historical serial connection with RS485 …
- Then wide adoption of IEEE 802.15.4 as *the* low power RF technology (2.4 GHz *and* 900 MHz)
- As expected (and this is the good news) several other low power technologies have emerged:

  Power Line Communication (PLC): key for the home and the Smart Grid

  Low power Wifi

  New RF technologies: IEEE 802.15.4g, Wavenis, …

Smart Objects networks are made of a variety of links

IP: The perfect fit !

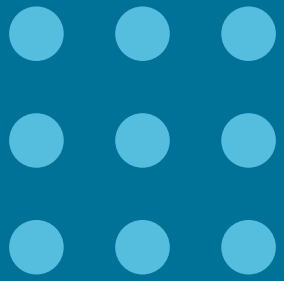
- Based on **open standards**: for interoperability, cost reduction and innovation … almost all proprietary protocols died …
- **Flexibility** in many dimensions:
  - Support a wide range of media
  - Support a wide range of devices
- **Always favor global than local optimum**: all protocols solving very specific issues never survived ☹ - We live in a fast changing world
- Highly secure
- **Plug & Play**
- **Scalable**

- Open standard: The Internet Engineering Task Force
- **Flexibility** in many dimensions:
  - Serial, SDH, FR, ATM, Ethernet, Wireless, Optical …
  - From cell phone to high speed routers
- **Always favor global than local optimum**: "IP if good enough for everything: from email to video to real-time protocols"
- A very secure and well proven
- **Billions of connected devices**

Do you remember that slide ?

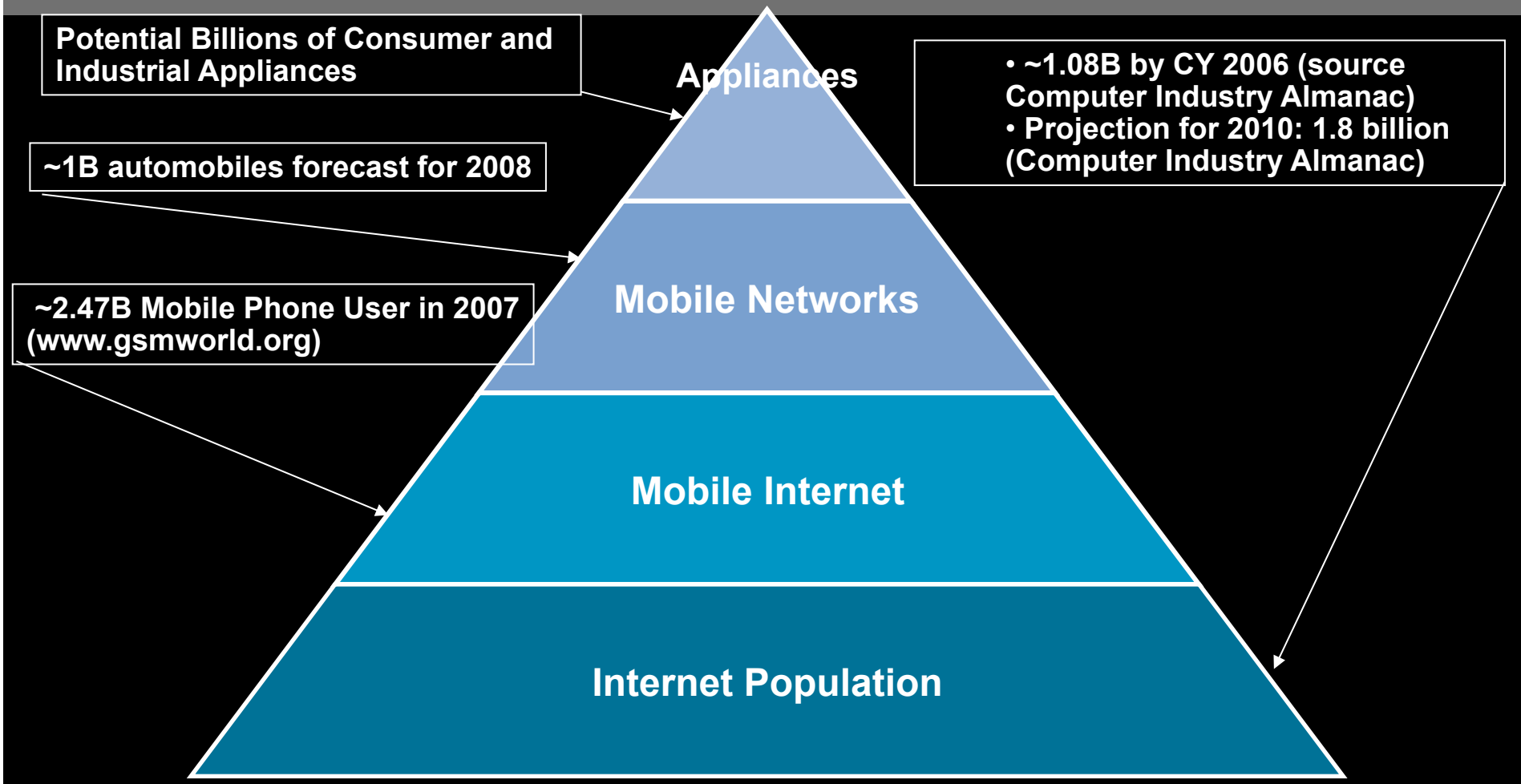
- The momentum of using IP for several applications is now there:
  - Smart Grid (with a needed migration strategy with today's legacy protocols)
  - In Buildings (with gateways helping with the transition)
  - In Smart City
  - In the Home Area Network
  - Adoption of IP at ISA for Industrial Automation
  - Some industries are still looking at it (Medical, Car industry)

Sill lots of technical work needed but the fundamental pieces are there ☺



IPv4 or IPv6 ?

Need for a Larger Address Space?



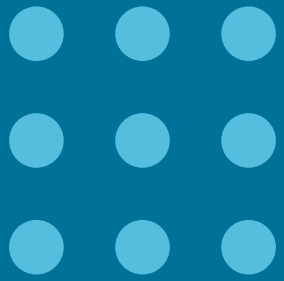
During the life cycle of a technology, a new product is often considered to have reached the early majority – or the mass market – after achieving 22 percent penetration.

IPv4 or IPv6 For The Internet Of Things?

- Solution to address exhaustion
- But also Stateless Auto-configuration thanks to ND (NS, DAD, RA messages).
- Various interesting optimization such as DNS records in RA,
- Issues with address size:

  No free lunch!

  Use of header compression (stateless and statefull)
- IETF Decision was to elect IPv6 as the protocol of choice for The Internet of Things



Isn’t IP too greedy for constrained devices ?

Open source lightweight stack delivered ➔uIPv6

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Cisco, Atmel and the Swedish Institute of Computer Science (SICS) Collaborate to Support a Future Where Any Device Can Be Connected to the Internet

One of the World's Smallest Open-Source, IPv6-Ready Protocol Stack Enables Cost-Effective Deployment of Sensor- Based 'Smart' Objects

SAN JOSE, Calif., and BANGALORE, India, October 14, 2008 - Cisco, Atmel and the Swedish Institute of Computer Science (SICS) today announced the availability of uIPv6, one of the world's smallest open-source, IPv6-ready protocol stack, which could enable every device, no matter how limited by power or memory to have an Internet Protocol address.

This collaborative project builds on Cisco's expertise in IP networking, Atmel's innovative low-power wireless hardware and SICS' knowledge in embedded operating systems design. "uIPv6 has the potential to impact a wide range of market verticals where automation is key, just as voice over IP did in enterprise telephony," said Rob Adams, senior director of Cisco's Corporate Development technology group.

"Smart" objects powered by a wide range of sensors and actuators are poised to enable a wide range of next-generation applications in building automation, industrial monitoring, smart cities and energy management, among many other areas. These applications help transmit information in the physical world about conditions or the environment (for example, temperature, light, motion, health status) to locations where the information can be analyzed, correlated with other data and acted upon.

The proliferation of such applications has however been held back by the large number of proprietary or semi-closed systems, and the cost associated with translating information before it can be effectively shared with other devices and systems. The use of IP as networking technology has long been recognized as the solution to this interoperability issue. Now, thanks to unique lower-layer energy management mechanisms and limited memory capacity, uIPv6 is highly power-efficient and ideal for most constrained devices.

Open-source uIPv6 includes standard IP applications and can be easily customized for specific requirements. It is integrated in the Contiki operating system developed by SICS, which provides all the necessary functionalities for networked smart objects. In addition, uIPv6's small footprint and memory usage allows it to run on the most constrained platforms. In particular, it was tested on Atmel's Raven wireless platform, chosen for its outstanding low-power performance.

"Efficient, low-power wireless systems require ultra-low-power embedded microcontrollers paired with excellent radio performance," said Magnus Pedersen, Atmel's director of product marketing, MCU Wireless Solutions. "The fact that Cisco and SICS chose the Atmel AVR Raven picoPower wireless platform as the basis for their uIPv6 and 6LoWPAN implementation confirms Atmel's leading edge in low-power embedded wireless technology."

uIPv6 is released under a permissive open-source license, and as a result can be used for both commercial and noncommercial applications.

"An open-source, standard-compliant, small-footprint IPv6 implementation is essential to enable the next generation of sensor network applications," said Adam Dunkels, senior scientist at SICS and Contiki project leader. Patrick Wetterwald, president of the IP for Smart Objects Alliance (IPSO) said, "By running an IPv6 stack, operating a network of sensors thus becomes as easy as operating a network of PCs, IP phones, or any other IP devices."

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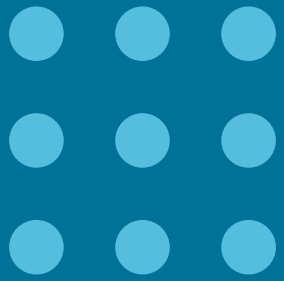
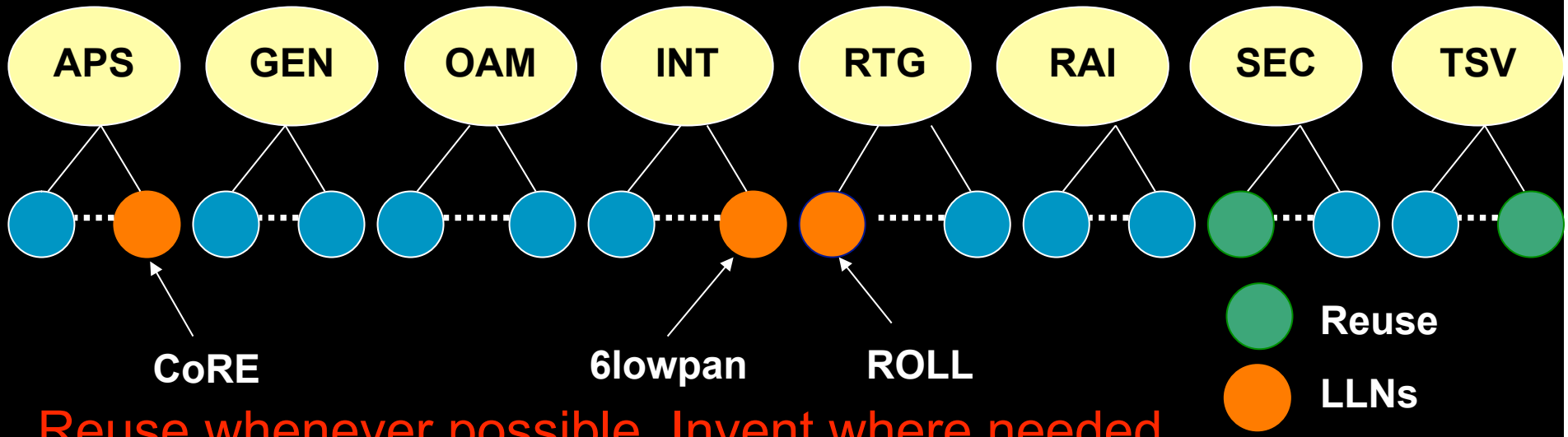
- ☑ Code base: Contiki OS/UIP stack + KAME stack
- ☑ All IPv6 features (except MLD) are implemented
  - Code size ≈ 11.5 KByte
  - RAM usage ≈ 0.2+**1.6** =1.8KByte
- ☑ Obtained IPv6 ready phase 1 logo
- ☑ Open source release October 14th, 2008
  - http://www.sics.se/contiki
- Other implementations: Archrock, Sensinode, PicosNet, Dust Networks, Gainspan, ZeroG, etc…



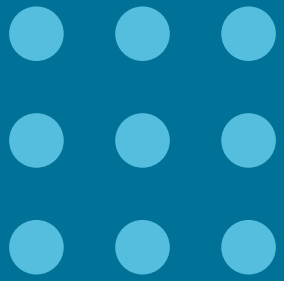
Standardization: The Internet Engineering Task Force (IETF)

IETF Update

- 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,



Reuse whenever possible, Invent where needed



6LoWPAN

What is 6lowpan ?

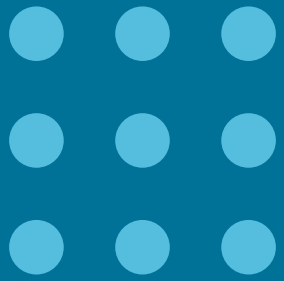
- 6LoWPAN is an adaption layer for Ipv6 over IEEE 802.15.4 links, not a protocol stack, full solution for smart objects networks!
- Why do we need an adaptation layer ?
- IEEE 802.15.4 MTU is 127 bytes
- Performs 3 functions:

  Packet fragmentation and re-assembly

  Header compression

  Mesh layer …

  ND in 6lowpan



Routing in Smart Object Networks

Where should Routing Take Place ?

- Historically, a number of interesting research initiatives on routing in WSN,
- Main focus on algorithms … a bit less on architecture
- Most work assuming the use of MAC addresses – L2 “routing” (mesh-under)
- Support of multiple PHY/MAC is a MUST: IEEE 802.15.4, LP Wifi, PLC (number of flavors), …
- Now … if what you want is a layered architecture supporting multiple PHY/MAC, there aren’t that many options …

IP !

Combine “Mesh Under” and Route Over”

IP Routing over 802.11s, 802.16J, 802.15.4

- *Haven’t we learned from the past ? Remember IP over ATM ?*
- IP layer with no visibility on the layer 2 path characteristic
- Makes “optimal” or “efficient” routing very difficult
- Layer 2 path (IP links) change because of layer 2 rerouting (failure or reoptimization) lead to IP kink metric changes. *How is this updated ?*
- There is still a need for an abstraction layer model but for Point to Point layer 2 links => Routing Metrics

Combine “Mesh Under” and Route Over”

Just Another major challenge: multi-layer recovery

- Require a multi-layer recovery approach
- Current models are timer-based:
  - Needs to be conservative and most of the time bottom-up
  - Increased recovery time for failures non recoverable at layer 2
- Inter-layer collaborative approaches have been studied (e.g. IP over Optical) => definitively too complex for current Sensor Hardware

IETF – Routing Protocols

- Long history in developing routing protocols at the IETF:
  - RIP,
  - OSPF,
  - IS-IS,
  - BGP
  - But also MANET: AODV, OLSR, NEMO, ..
- And non standardized IP routing protocol also exist: EIGRP

Routing for Smart Objects

Current Internet

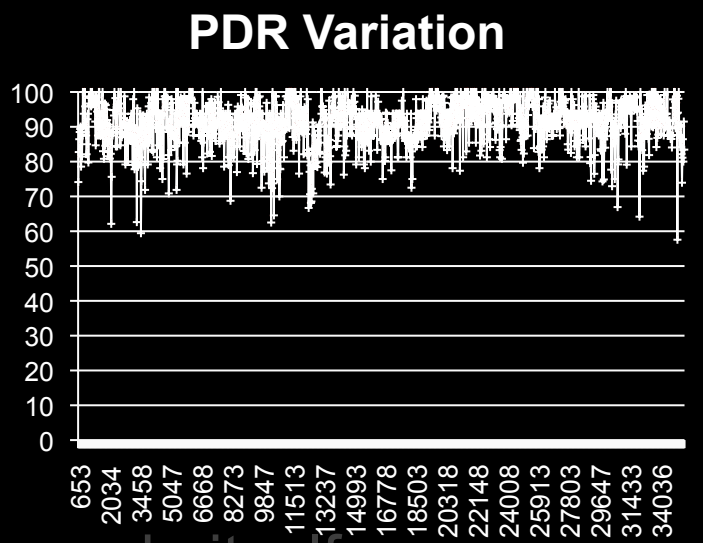
- Nodes are routers
- IGP with typically few hundreds of nodes,
- Links and nodes are stable,
- Nodes constraints or link bandwidth are typically non issues,
- Routing is not application-aware (MTR is a vanilla version of it)

Sensor Networks

- Nodes are sensor/ actuators&routers
- An order of magnitude larger in term of number of nodes,
- Links are highly unstable and Nodes die much more often,
- Nodes/Links are highly constrained
- Application-aware routing, in-Band processing is a MUST

A reminder of the technical challenges

- Energy consumption is a major issue (for battery powered sensors/controllers),
- Limited processing power
- Very dynamic topologies:
  - Link failure (LP RF)
  - Node failures (triggered or non triggered)
  - Node mobility (in some environments),
- Data processing usually required on the node itself,
- Sometimes deployed in harsh environments (e.g. Industrial),
- Potentially deployed at very large scale,
- Must be self-managed (auto-discovery, self-organizing networks)



Don’t be surprised to see significantly different design choices

- All routing protocols used in Service Providers’ network are link state
- Scalability is a must but clearly not the same order of magnitude (most ISIS network are L2 flat)
- Convergence time is key: ~ 10s of ms
  - Low BER
  - Immediate triggering (Link layer trigger or Fast KA (BFD))
  - Use of pre-configured backup path with FRR (IP/MPLS)
  - Use of dampening in case of rare link flaps
- No need for node metrics/constraints

SP’s networks are quite different

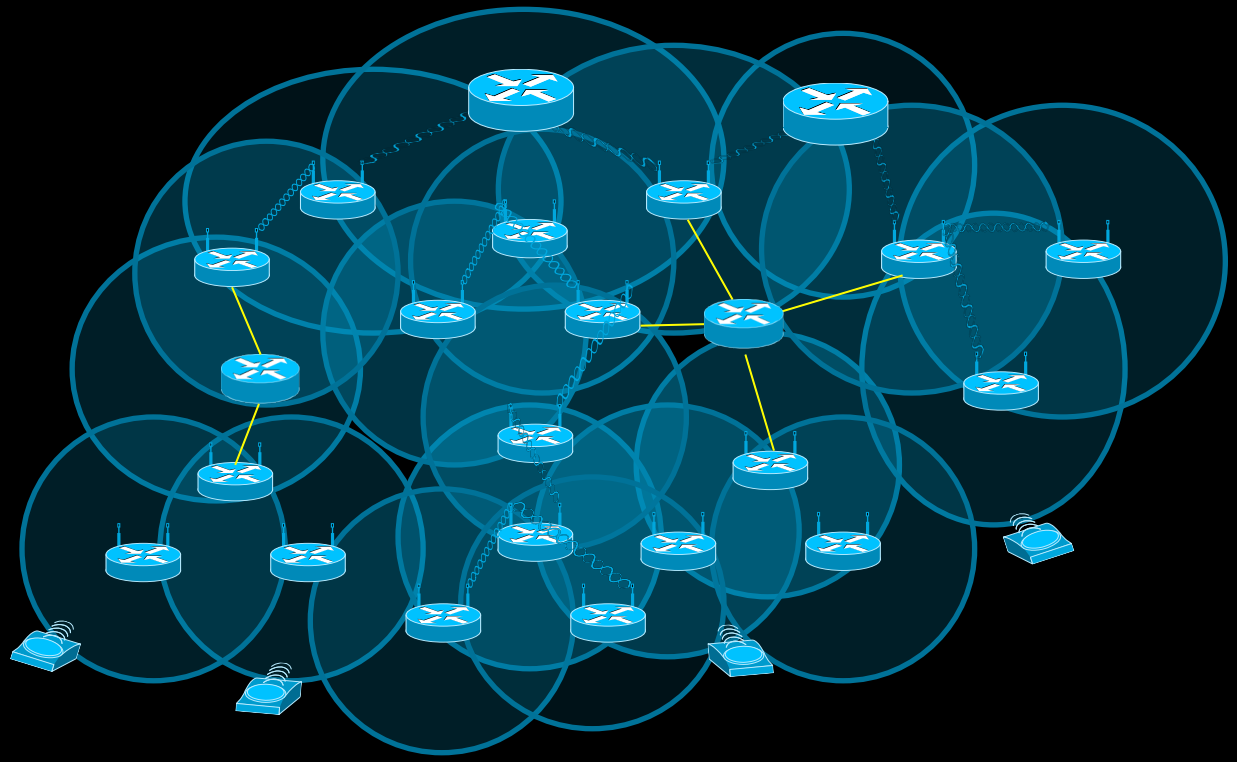
Routing Over Low power and Lossy Link (ROLL) WG

- Working Group Formed in Jan 2008 and already re-chartered

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

  Co-chairs: JP Vasseur (Cisco), David Culler (Arch Rock)
- Mission: define Routing Solutions for LLN (Low power and Lossy Networks)
- Very active work with a good variety of participants with at first little IETF background
- Rechartered to specify the routing protocol for smart objects networks (after protocol survey)
- DT formed (and now dissolved)
- Several proposals: one of then adopted as WG document, RPL

RPL: a DV routing protocol building a colored DAG



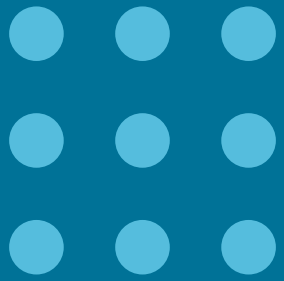
RPL is specified in draft-ietf-roll-rpl

Already about 10 implementations

- RPL: DV Based Routing Protocol – DAG Formation
- The DAG is colored (Constrained Based Routing)
- Rules for parent selection based on metric, OF and loop avoidance
- Under-react is the rule !! (local versus global reroutes) to cope with transient failures
- Governed by Trickle Timers

Routing Metrics in LLNs

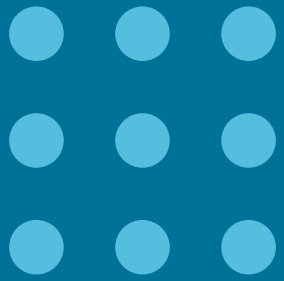
- Defined in draft-ietf-roll-routing-metrics
- Node metrics/constraints
  - Node state and Attribute: aggregator, overload bit (collapsing various resources states) in the presence of sustained overload
  - Node Energy: power mode, estimated lifetime
- Link metrics/constraints
  - Hopcount
  - Throughput
  - Latency
  - Link Reliability: ETX (link layer agnostic) and LQL (from 0 to 3)
  - Link Colors (administrative): can be used as a constraint or a metric



CoRE

CoRE in one Slide

- Working Group meeting for the first time in Anaheim
- **Constrained RESTful Environments (core)**
- Core will define a framework for a limited class of applications that deal with the manipulation of simple resources on constrained devices
- WG will define a Constrained-node/network Application Protocol (CoAP) for the manipulation of Resources on a Device.
- A key WG !

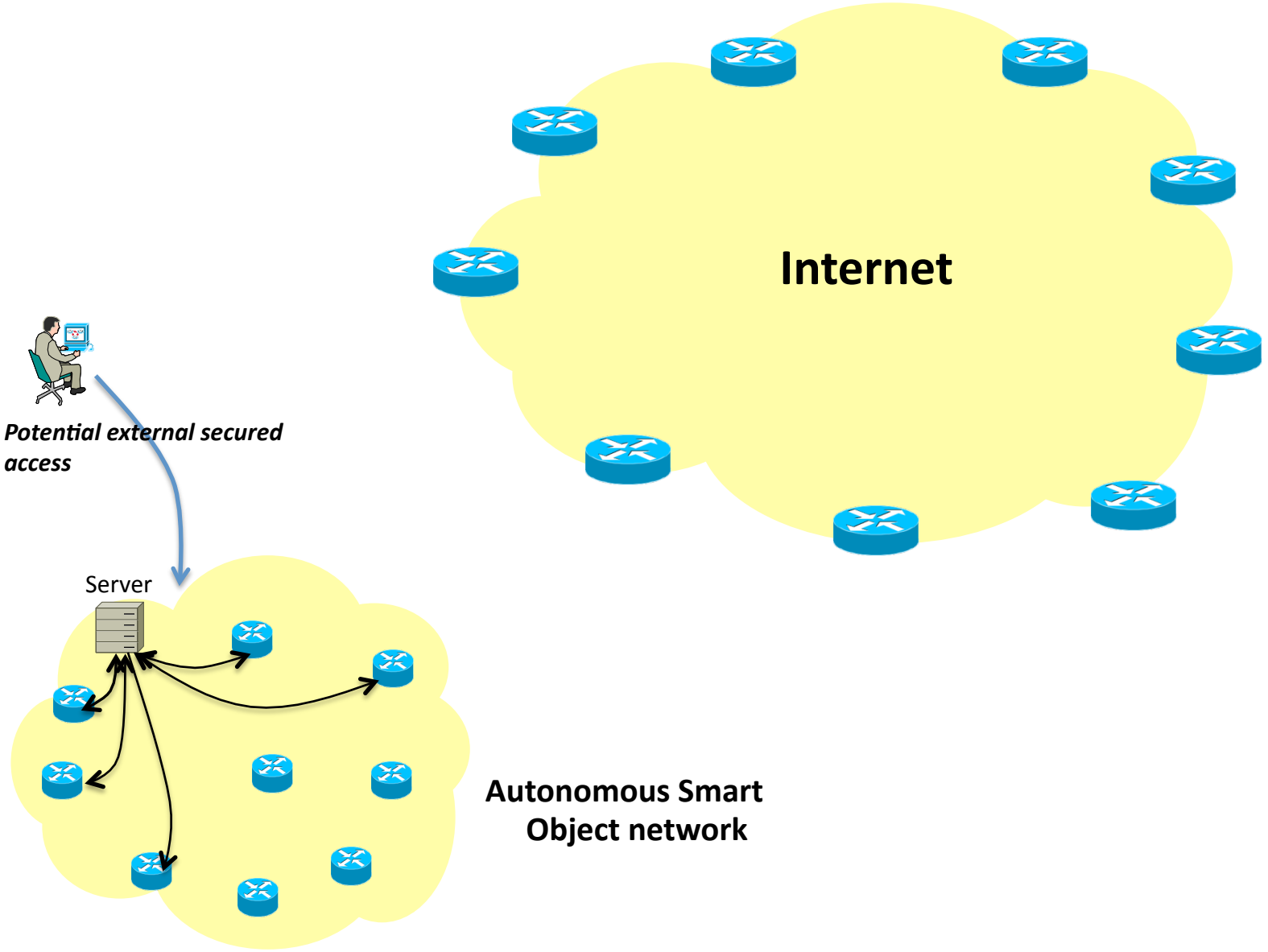


Connectivity Models

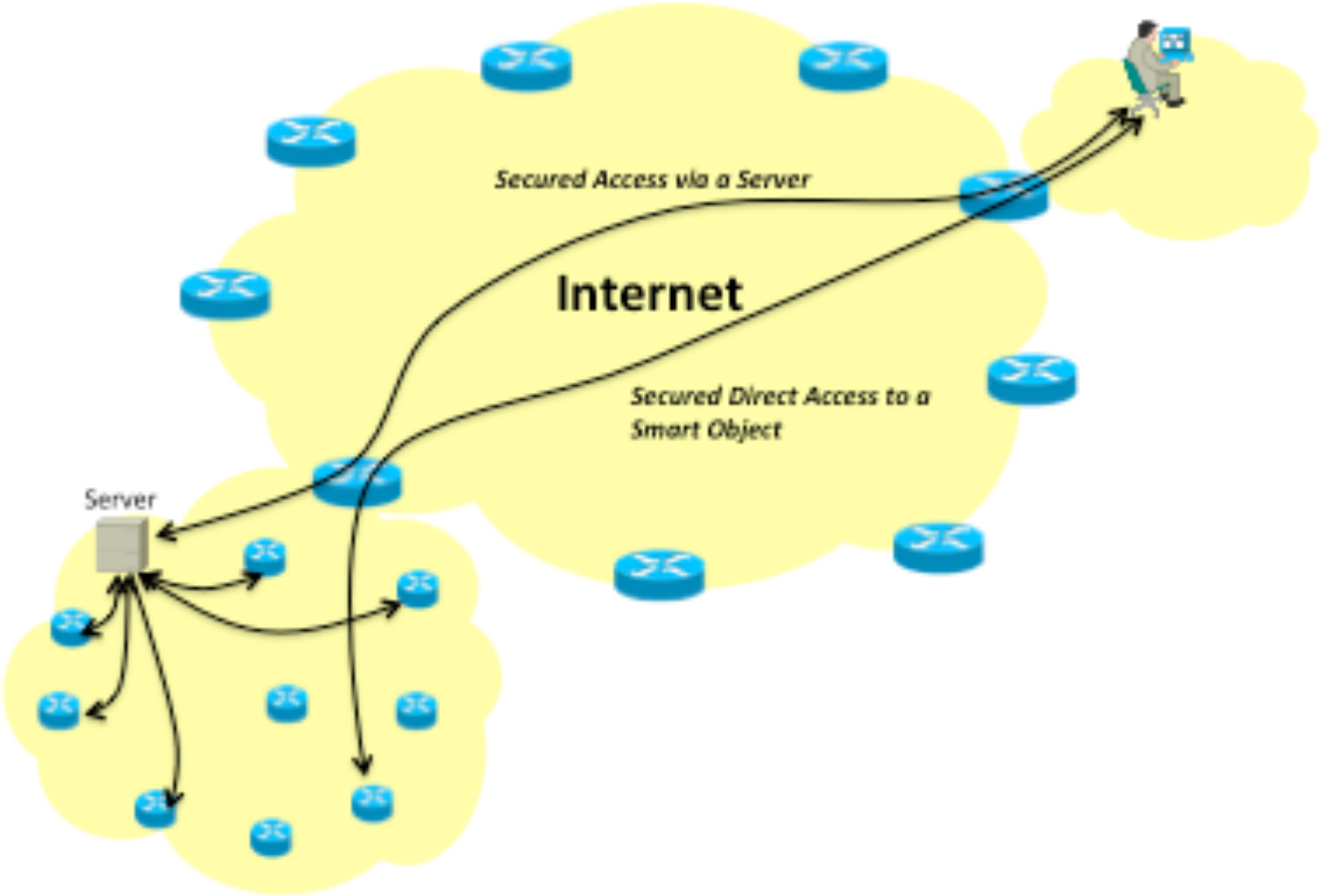
Connectivity Models

- 3 models (and may be more!)
  - Autonomous Smart Object Networks
  - The “True” Internet of things
  - The Extended Internet

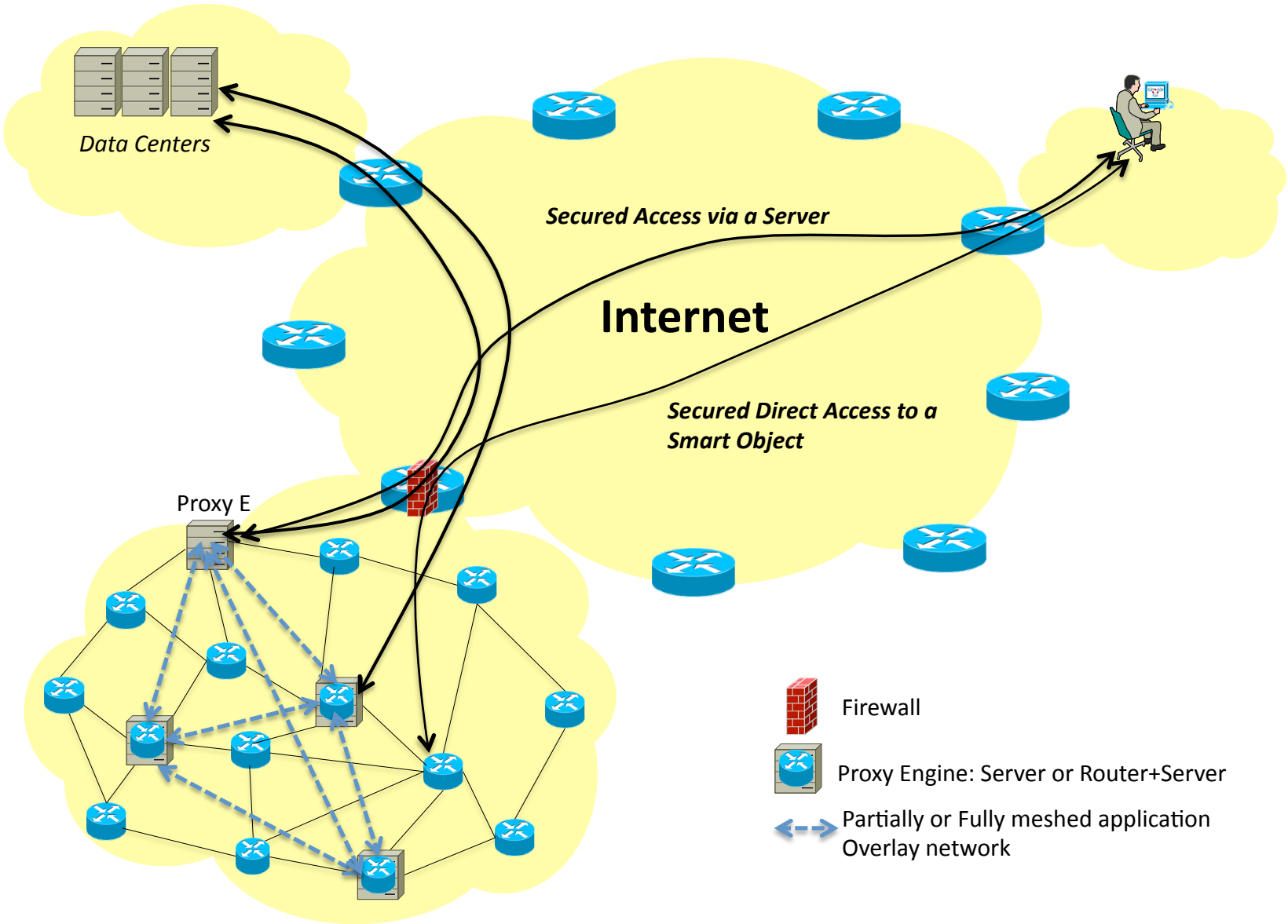
Autonomous Smart Object Networks

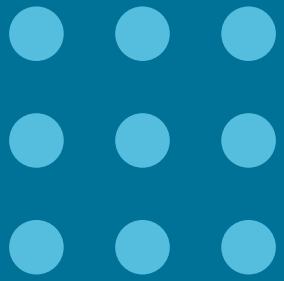


The Internet Of things



The Extended Internet Application Layer Overlays





Other technical components

What else do we need for the Internet of Things ?

- Applications optimization for Smart Objects ?
- A new transport layer ?
  - Issues with TCP in highly loosy networks
  - *Mid-point ACK and flow control as opposed to end-to-end?*
  - *New Flow control mechanisms?*
- Integration with DTN protocols for extreme cases of loose connectivity
- Service Discovery
- Lightweight security (IPSec, IKE, …)
- Embedded services

Conclusion

- Several major applications: Smart Grid, Green, Industrial, Connected building/homes, Smart Cities.
- This required some efforts but … there is a momentum around IP
- Major progress in several key areas:

  IP-based technologies: 6lowpan, RPL and now CoRE

  IPSO alliance 

  Adoption of IP by several other SDOs/alliance: Zigbee/IP for SE2.0, Bacnet, ….
- Still lots of interesting work to do ! Constrained application protocols (CoAP), HTTP Rest, routing, service and node discovery, lightweight security, connectivity models, …

Thank you for your attention