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Several major applications are now there.

- Energy Saving (I2E)
- High-Confidence Transport and assets tracking
- Predictive maintenance
- Improve Productivity
- New Knowledge
- Healthcare
- Smart Cities
- Agricultural
- Industrial Automation
- Intelligent Building
- Smart Home
- Smart Grid
- Defense
One of the major issues 3+ years ago …

- High number of *proprietary or semi-closed* solutions: Zigbee, 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*

... with ... The usual “My environment has specific requirements and requires a specific solution” syndrome

=> Local versus global optimum !!

An innovation stopper: one (proprietary) “solution” per application: vertical versus horizontal architectures (IP)
Do you remember that slide?

- Use of IP:
  - Smart Grid (with a needed migration strategy with today’s legacy protocols)
  - In the Building (with gateways helping with the transition)
  - In Smart City (green field)
  - In the Home Area Network
  - Adoption of IP at ISA for Industrial Automation
  - Excellent progress on Zigbee-IP!
  - Some industries are still looking at it (Medical, Car industry)

Sill technical work needed but the fundamental pieces are there 😊: 6LowPAN, RPL, Core

Deployments are limited in scope and scale,
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 several functions:
  - Packet fragmentation and re-assembly
  - Header compression
- 6LoWPAN ND is now almost finalized
The new IPHC Compression Technique

- HC1 and HC2 used for link local addresses
- IPHC provides efficient compression of Global Link addresses (thanks to context) and Multicast addresses
- More granular compression of the Traffic Class and Flow Label IPv6 field
- Supports the compression of the Hop Limit field
- Modular compression of the source and destination addresses (128/64/16/0 addresses) – 0=> Link Local + IEEE 802.15.4 for the IID
- More than likely will deprecate RFC4944 for header compression
Routing in Smart Object Networks
Routing Over Low power and Lossy Link (ROLL) WG

- Working Group Formed in Jan 2008 and already re-chartered
  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 them adopted as WG document, RPL
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
RPL: a DV routing protocol building a colored DAG

- 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

RPL is specified in draft-ietf-roll-rpl

Not a WSN routing protocol!
Low Power and Lossy (LLN) Network

ETX (=1 when not indicated)
=> reflect the link quality

Step 1
LBR
DIO message multicasted by the root

Step 2
Every router runs an algorithm to choose a parent based on an objective (best quality path, highest bandwidth link,....)

Step 3

Final

The DAG (Direct Acyclic Graph) continues to build … with siblings also (removed from the core spec)
Concept of Multiple DAGs

Physical topology

DAG instance 1: high quality – no battery operated nodes
DAG Instance 2: low latency

Battery Operated Node

- Poor Quality (LQL=3)
- Fair Quality (LQL=2)
- Good Quality (LQL=1)
- Latency in milliseconds

DAG Instance 1: high quality – no battery operated nodes
DAG Instance 2: low latency
New set of metrics

- Requirement for both link and node metrics and constraints in LLNs
- Routing objects can be used as a metric or as constraint
- Constraints used for constrained-based routing
- Some metrics are dynamic => use of low pass filters and multi thresholds to avoid oscillations
- Support of local and global metrics (path cost)
- Min, max and cumulative metrics
- Reliability metrics: ETX (mono-dimensional but Link layer independent) + Link Quality Level
- Use of Objective functions in RPL: defines the DAG Color (set of metrics and constraints to use)
Powerline Communication (PLC) standards
Next Generation PLC: IEEE and ITU-T

- Convergence towards *one* standard: next-gen PLC
  - IEEE P1901.2: current discussion on PHY (easy), MAC (harder – different addressing proposals), SAP for IPv6 support, discussion on addressing and L2 versus L3 routing. **Motion passed to support IPv6 and RPL**
  - ITU G.hnem: fast progress close to CPL G3, discussion on L2 versus L3 routing, **adoption of IPv6**

- Attempt to quickly come to a stable standard within a six months timeframe
Zigbee/IP
Zigbee/IP

- Group within Zigbee in charge of the certification of an IP-based solution (not all Zigbee groups are IP-based) for energy management
- Good liaison with the IETF
- Selection of IP protocols to build a solution “package” based on:
  - Main interest in IEEE 802.15.4 (for the time being)
  - 6LoWPAN: HC (Header compression) and 6LoWPAN ND
  - RPL (Routing)
  - MDNS (Discovery)
  - Applications of their own
- Active interoperability testing: successful test event in August with 9 implementations (15.4, 6lowpan, RPL, …)
The Wavenis Alliance
Wavenis

- Wavenis-OSA is an alliance specifying a PHY/MAC (apps being discussed) for ULTRA low-power communication, long range
- Originally non-IP, based on Elster (Coronis) implementation (millions of meters deployed)

**PHY:**
- Data rates: 10-20Kbits/s, GFSK modulation, RSSI,
- RF: 868MHz (Europe), 915MHz (North America), 433MHz
- High sensitivity (BER=1%)

**MAC**
- Frequency hopping, CSMA/CA, ACK, CRC, Handle fragmentation, Sophisticated power management (preamble detection, low energy listening mode), EUI-64 address (no need for DAD)

- Now layered, with networking layer based on IPv6 and RPL for routing
The IP for Smart Object Alliance (IPSO)
Objectives of IPSO

- Create awareness of available and developing technology with IP for Smart Objects
- Generate tutorials, white papers and highlight use cases
  - [http://www.ipso-alliance.org/Pages/DocumentsAndWhitePapers.aspx](http://www.ipso-alliance.org/Pages/DocumentsAndWhitePapers.aspx)
- Complement the IETF, IEEE, … which define standards, but does no marketing
- Link companies that support IP based sensing and control systems
- Coordinate and combine member marketing efforts
- Support and organize interoperability events
Support Activities

- IETF 6LoWPAN, ROLL, CORE Working Groups
- ISA100 Industrial Wireless
- IEEE Working Groups
- ITU-T

Formal liaisons

- IPv6 Forum
- Zigbee alliance

On-going Activities

- Interoperability Testing
- Architecture Design
- Technology Demonstrations
- Use Cases / White Papers
- Tutorials, Webinars and Educational Materials
- Joint activity with IPv6 forum on IPv6 ready certification dedicated to smart objects
Why IP?

- The emerging application space for smart objects requires scalable and interoperable communication mechanisms that support future innovation as the application space grows. IP has proven itself a long-lived, stable, and highly scalable communication technology that supports both a wide range of applications, devices, and underlying communication technologies. The IP stack is lightweight and runs on tiny, battery operated embedded devices. IP therefore has all the qualities to make “The Internet of Things” a reality, connecting billions of communicating devices.

Lightweight OS

- Historically, smart objects have used a plethora of communication technologies, both at the physical and medium access control layers, and at upper layers. The upper layers of the communication stack remain either proprietary or specified by exclusive alliances. This plethora of solutions renders interoperability between different sensor networks difficult. It also makes the seamless integration of sensor networks with existing IP networks impossible. IP is an ideal solution to this end-to-end interoperability issue. However, the adoption of IP as the Layer-3 protocol to connect wireless or wired smart objects has been impaired by the common belief that IP is not well-suited for the memory and energy constraints of such devices. In this white paper we give insights on key implementation aspects, based on the experience of three interoperable IPv6 stacks.

6LoWPAN

- IP for Smart Objects seeks to extend the use of IP networking into resource-constrained devices over a wide range of low-power link technologies – IEEE 802.15.4 represents one such link. Extending IP to low-power, wireless personal area networks (LoWPANs) was once considered impractical because these networks are highly constrained and must operate unattended for multyear lifetimes on modest batteries. Many vendors embraced proprietary protocols, assuming that IP was too resource-intensive to be scaled down to operate on the microcontrollers and low-power wireless links used in LoWPAN settings. However, 6LoWPAN radically alters the calculation by introducing an adaptation layer that enables efficient IPv6 communication over IEEE 802.15.4 LoWPAN links.

Security Introduction

- Security is as important in smart object networks as it is in traditional computer networks, if not more so. By leveraging well-established security mechanisms and networking standards, and adapting them appropriately for resource-constrained environments, we can enhance the security of smart objects, their data and the networks in which they participate. In this white paper we discuss smart object applications and relevant threats, evaluate various approaches to securing against specific threats, offer some practical guidelines for building security into smart object networks, and finally tackle some common misconceptions about securing these devices.

02/01/2009
IPSO ALLIANCE ANNOUNCES FREE TECHNICAL WEBINAR SERIES
Sessions to Address Growing Demand for Users Implementing IP for Smart Objects

November 30, 2010 at 8:00 AM PST - “6LoWPAN for IP Smart Objects,” will provide attendees information on where 6LoWPAN fits within the IPv6 architecture and to what scenarios it is applicable. The session will also focus on how 6LoWPAN efficiently transports IPv6 datagrams and the necessary services needed to maintain an IPv6 sub network.

December 14, 2010 at 8:00 AM PST- “RPL - The Routing Protocol for the Internet of Things,” will provide a technical overview of RPL, the routing protocol for IP smart object networks that has been specified by the IETF ROLL Working Group. The session will also provide an overview of applications of RPL such as smart grid and smart cities and an analysis of other use cases.

January 18, 2011 at 8:00 AM PST “Embedded Web Services,” will cover how new standards are enabling embedded web services for even the most constrained IP Smart Objects and networks. Today web services are key to powering modern enterprise IT systems. Web service technology is playing an equally important role as IP Smart Objects are rapidly being integrated into backend systems in applications such as smart energy, building automation and asset management.

To register for these webinars, please visit www.ipso-alliance.org
Conclusion

- Once again IP is not just a set of protocols but an architecture,
- Starting with IPv6 is the way to go,
- Almost 3 decades of work to provide multi-service networks thanks to a myriad of technologies (QoS, high reliability, multicast, security, …)
- IP end-to-end avoids complex protocol translation gateways and decreases network management complexity!
- Provides flexible networks for decades to come => minimizing OPEX/CAPEX and preserve investments
- IP end-to-end is the key of success to enable new services and innovation
Thank you for your attention

Questions?