The Internet of Things: What’s Up Next?

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JUST THE BEGINNING

When one person connects, their world changes.

With everything connected, our world changes.
A VISION

In the networked society things, places, and real-world processes are first-class citizens on the Internet.

And they network – for the benefit of society, life and business.
THE INTERNET OF THINGS

- Monitoring and controlling real world objects – provide smartness
- Meeting the needs of enterprises, people and society
- Application domains are endless
- The underlying technology is embedded networked computing with sensors, actuators and tags
DRIVERS AND CHARACTERISTICS

Lean | Green | Safe | Innovation | Collaboration

Fun | Servitization | Marketplaces | Participation
Transformation - The Big Picture

POWER SHIFT
RESOURCES & ENVIRONMENT
GLOBAL CONNECTEDNESS
ENVIRONMENT
URBANIZATION

INTERNET OF THINGS
DATA AND INSIGHTS
SOCIAL MEDIA
CLOUD & NETWORKS
PERMISSIONLESS INNOVATION & OPEN GLOBAL INTERNET
IS IT HAPPENING?
WHAT IS NOW AND NEXT?

“THEN AND NOW”
› Metering
› Telematics
› Point-of-Sale
› Healthcare
› Security and Surveillance
› Smart Grid
› Transport

“RECENT”
› Wearables
› Sports and wellness
› Home automation
› Smart appliances
› Industrial
› Streetlights

“NEXT”
› Manufacturing
› Home convenience
  (ambience, lighting, assisted living)
› Food safety
› Agriculture
› Water
› Natural resources
› Materials
› Self-driving vehicles
› …. the unpredictable
Dual-Core ARM Cortex-A9 Module
1 GB RAM and 8 GB Flash
(Source: linuxgizmos.com)
NEW ARM-POWERED CHIP AIMS FOR BATTERY LIFE MEASURED IN DECADES

Atmel's 32-bit SAM L controllers, shipping soon, take low power to new extremes.

by Sean Gallagher - Mar 31, 2015 1:45am EEST

Low-power ARM CPU
(Source: arstechnica.com)

Also matches what is becoming achievable in mobile networks
LOW POWER

Energy consumption of various tasks on 8-bit CPUs
(Source: Margi et al at IEEE WiMAN 2010)
5G AND NETWORKED SOCIETY

- Multi-domain Performance
- Foundation for Efficient Industries and Society
- Energy Performance
- Global Standard
- Mass Market Personalized TV
- Massive Machine Type Communications
- Critical Machine Type Communications
MACHINE TYPE COMMUNICATION

- Monitoring & automation of buildings, city infrastructure, smart metering
  - Long battery life
- Smart agriculture and farming
  - Low cost
- Connected vending machines
  - Massive numbers
- Logistics, tracking and fleet management
  - Long range
  - Small data
- Remote patient monitoring
- Smart grid distribution automation
  - Reliable real-time communication
- Autonomous vehicles
  - High reliability
- Remote control of machines
  - Remote manufacturing, training, surgery
  - Low latency
- Industrial manufacturing and control
  - High availability

Critical machine-type communication

Factory Automation

Motion Control

Intelligent Transportation Systems

Smart Grid

Process Automation

Automated Guided Vehicle
MATERIALS

Smart clothing technology (Source: digitaltrends.com)

Internet of Food projects (Source: thnk.org)

INTERNET OF FOOD
MATERIALS

Concrete instrumentation
(Source: Construction and Building Materials Vol 22)

Temperature and moisture monitoring in concrete structures using embedded nanotechnology/microelectromechanical systems (MEMS) sensors
Ashley Norris¹, Mohamed Saatif², Peter Romine³

Smart igloos
(Source: Arkko & Keränen, Ericsson Labs)

Cement (Photo: Ouassame Zrafi, Wikipedia)
The intelligence is in the network, not the devices

Cloud – connecting the devices together

User interfaces modeled on social networking
A shift of focus

- Devices
- Connectivity
- Closed

- Data
- Analytics
- Automation
- Open
MORE THAN CONNECTED DEVICES

Enterprise business support and integration: CRM, ERP, ...
User exposure: Retail, Portals, Visualizations, APIs
Marketplaces: Brokering, transaction mgmt,

Common applications: Preventive Maintenance, Automation, Items Tracking, Building Automation, Farming Control, Environmental Monitoring, ...

Knowledge Management and Processing: Real World Model, Resource modelling, Analytics, Context Awareness, Reasoning, Actionable services, Learning, Automation, ...

Common enablers: Device and Resource Management, Data and Event capture, Data Warehousing, Cloud, Distributed Execution Environment

Connectivity: Cellular, Fixed, Satellite, Capillary Networks, Managed Connectivity

Monitor&Control: Sensors, Actuators, Tags, Devices, Gateways, WSAN

Real World Assets: Building, Smart Grid, Vehicle, Body,...
Necessary developments

<table>
<thead>
<tr>
<th>Devices</th>
<th>Intelligent software</th>
<th>Semantic interoperability</th>
<th>Open</th>
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NETWORKED VALUE CHAINS

70% of all computer chips do not go into computers

John Deere CEO Bob Lane says he doesn’t make tractors but rather “sophisticated mobile information factories.”

- GPS shows where it is
- Microwave sensors measure cotton flow
- RFID tags let processors know origin of each bundle
- Wireless communications
- Computing power of 8 PC’s
CONSUMER
“Instant bicycling – just add muscles”

- Heart rate
- Wireless gears
- Cadence
- Power
- Spin
- GPS
- Temperature
- Barometric pressure
- Weather forecast
- Navigation
- Internet
- Apps
- Accelerometer
- Gyroscope
- Training coach
- Autonomous gear shifting
- Crash/emergency detection
- Realtime route planning
- Virtual racing
- Social media, ...

“Instant bicycling – just add muscles”
INDUSTRIAL

Remote operation

"MINING 2.0"

For a safer and healthier working environment

For a more efficient operation
"PERMISSIONLESS INNOVATION"
SOME AREAS OF INNOVATION

IP itself:
Building any communications services on top of IP

WebRTC:
Real-time communications in your browser

The Web:
Both for browsing and building applications

SDN:
Programmable networking

Web of Things:
Building IOT systems on the Web Protocols
EXPERIENCES

- Legacy devices are moving to an all-IP model
- It is important to reach interoperability at all layers; formats and web interfaces are very important too, not just IP
- The key is general purpose technology (3G, WLAN, web)
- Web tools is the way the market is going
THE WEB OF THINGS (WOT)

This is a very attractive model for developing smart object applications

- Very successful for other applications
- Widely available tools & millions of programmers
- Simple and well-defined
- “Permissionless innovation”
MAKE IOT GO MAINSTREAM

› Go IP
  – Reduce technology fragmentation
  – Drive IP to the “tiniest of devices”

› Go Web
  – Use standard web technologies
  – Ease enterprise SOA integration
  – Attract the global developer community

› Go Simple
  – Make devices application generic
  – Drive value from devices to cloud enablement
  – Break device silos
IETF & THE INTERNET OF THINGS

› Basic IP communication
  – IP(v6) over Foo
  – 6TISCH WG

› Web tools
  – CORE WG & COAP
  – HTTPBIS WG & HTTP/2
  – JSON, JOSE WG

› Security
  – TLS, DTLS, JOSE
  – DICE WG, ACE WG

› Routing
  – Mesh networking
  – Ad hoc networks
  – ROLL WG & RIPL
  – MANET WG & OSLR, AODV, …

› Configuration
  – Autonomic networking
  – HOMENET WG
  – ANIMA WG

› Other
  – EMAN WG
IOT AND INTERNET GOVERNANCE

First answer: nothing changes
No new Internet Governance needed
- Does not need new naming
- Most operations are in databases & private clouds
IOT AND INTERNET GOVERNANCE

Privacy
- Technical and practical issues
- User ownership of data

IPv6
- Important for reachability

Market creation
- Ensure competitive market
- Many players for different roles

Interoperability
- Competition
- Switching costs
- Long-life devices
SOME CONCLUSIONS

Building the networked society

• Machine-type communication is a fundamental building block

• Microelectronics, mobile networks, IP, the web protocol stack are all evolving to meet the needs

• The ability to connect different pieces together in innovative & open ways is a key enabler