Ubiquitous Wireless Sensor Networks and future “Internet of Things”

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Ubiquitous Sensor Network

- Any place, any thing using wireless tags/nodes - **Ubiquitous**
- Sensing ID and environmental information - **Sensor**
- Real time monitoring and control using a - **Network**
Internet of Things (IoT)

- A world-wide network of uniquely addressable interconnected objects, based on standard communication.
- Wireless identifiable devices are able to seamlessly interact and communicate with the environment and with other devices.

IoT is referred together with terms like Ambient Intelligence, Ubiquitous Computing, Pervasive Computing, or Pervasive Networks and Semantic Web.
Connectivity for *anything, anytime, any place, anyone.*

- Connect objects and devices to large databases and networks using simple, and cost effective systems of item identification so data about things can be collected and processed.
- Ability to detect changes in the physical and environmental status of things, using sensor technologies.
- Devolving information processing capabilities to the edges of the network using embedded intelligence in the things.
- Miniaturization and use of nanotechnology so smaller and smaller things will have the ability to interact and connect.
Internet of Things (IoT)

- Connectivity for *anything, anytime, any place, anyone.*
Smart Systems on Tags

- Sense
- Actuate
- Identify
- Interact
- Interface
- Communicate
Wireless Systems Characteristics

- **Wireless**
  - Limited bandwidth, high latency
  - Variable link quality and link asymmetry due to noise, interference, disconnections
  - Easier snooping
    - Signal and protocol processing

- **Mobility**
  - Determine variability in system design parameters:
    - Connectivity, bandwidth, security domains, location awareness
  - Protocol processing

- **Portability**
  - Limited capacities (battery, CPU, I/O, storage, dimensions)
  - Energy efficient signal and protocol processing

Source: Momenta neck-worn PC
Communication Technologies

M2M/T2T
- RFID (424kb/s, 7m, 13.56MHz, 866-960MHz)
- RFID (433MHz, 2.45GHz)
- ZigBee* (250kb/s, 10m, 2.47GHz)
- ZibBee*–a (20kb/s, 75m, 900 MHz)
- RuBee
- RuBee
- WirelessHart
- ISA 100

Personal

WPAN

Local

WLAN

Metropolitan

WMAN

H2M/H2H
- Bluetooth (750kb/s, 10m, 2.47GHz)
- Low Power Bluetooth
- UWB (50Mb/s, 30m, Wide Range)
- Wi-Fi (50-320Mb/s, 100m, 2.4-5.8GHz)
- Wi-Max (70Mb/s, 50Km, 2-11GHz)
- UMTS, CDMA (2Mb/s), EDGE, MBWA

Passive – Low Cost

Active – Mid/High Cost
## Wireless Technologies - RFID

<table>
<thead>
<tr>
<th>Frequency Band</th>
<th>Frequency Range</th>
<th>Wavelength</th>
<th>RFID Frequency</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>LF</td>
<td>Low Frequency</td>
<td>30kHz to 300kHz</td>
<td>10km to 1km</td>
<td>30-50kHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>125/134kHz</td>
<td>USID</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>131/450kHz</td>
<td>ISO 18000-2</td>
</tr>
<tr>
<td>MF</td>
<td>Medium Frequency</td>
<td>300kHz to 3MHz</td>
<td>1km to 100m</td>
<td></td>
</tr>
<tr>
<td>HF</td>
<td>High Frequency</td>
<td>3MHz to 30MHz</td>
<td>100m to 10m</td>
<td>6.78MHz</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>7.4-8.8MHz</td>
<td>ISO 18000-3</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>13.56MHz</td>
<td>ISO/IEC 15693</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>27MHz</td>
<td>ISO/IEC 14443/NFC</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ISO/IEC 10536</td>
</tr>
<tr>
<td>VHF</td>
<td>Very High Frequency</td>
<td>30MHz to 300MHz</td>
<td>10m to 1m</td>
<td>125MHz</td>
</tr>
<tr>
<td>UHF</td>
<td>Ultra High Frequency</td>
<td>300MHz to 3GHz</td>
<td>1m to 10cm</td>
<td>433MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>840-956MHz</td>
<td>ISO 18000-7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.45GHz</td>
<td>18000-6 Type A, B, C</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>EPC C1G2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>IEEE 802.11</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ISO 18000-4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>IEEE 802.15 WPAN</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>IEEE 802.15 WPAN Low Rate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>IEEE 802.15 RFID</td>
</tr>
<tr>
<td>SHF</td>
<td>Super High Frequency</td>
<td>3GHz to 30GHz</td>
<td>10cm to 1cm</td>
<td>3.1-10,6GHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5.8GHz</td>
<td>IEEE 802.15 WPAN UWB</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>24.125GHz</td>
<td>ISO 18000-5</td>
</tr>
<tr>
<td>EHF</td>
<td>Extremely High Frequency</td>
<td>30GHz to 300GHz</td>
<td>1cm to 1mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MMID</td>
</tr>
</tbody>
</table>
Wireless Technologies - WSN

- IEEE 802.15.4
- ZigBee
- WirelessHART
- ISA100.11a
- 6LoWPAN
- Low Power Bluetooth
- RFID
# Wireless Technologies - Comparisons

<table>
<thead>
<tr>
<th></th>
<th>ZigBee</th>
<th>Bluetooth</th>
<th>UWB</th>
<th>Wi-Fi</th>
<th>Proprietary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard</strong></td>
<td>IEEE 802.15.4</td>
<td>IEEE 802.15.1</td>
<td>IEEE 802.15.3a (TBR)</td>
<td>IEEE 802.11 a, b, g, n</td>
<td>Proprietary</td>
</tr>
<tr>
<td><strong>Industry Groups</strong></td>
<td>ZigBeeT Alliance</td>
<td>Bluetooth SIG</td>
<td>UWB Forum &amp; WiMedia Alliance</td>
<td>Wi-Fi Alliance</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Topology</strong></td>
<td>Mesh, Star, Tree</td>
<td>Star</td>
<td>Star</td>
<td>Star</td>
<td>P2P, Star, Mesh</td>
</tr>
<tr>
<td><strong>RF Frequency</strong></td>
<td>868/915MHz 2.4GHz</td>
<td>2.4GHz</td>
<td>3.1-10.6GHz</td>
<td>2.4GHz 5.8GHz</td>
<td>433/868/900MHz 2.4GHz</td>
</tr>
<tr>
<td><strong>Data Rate</strong></td>
<td>250Kbps</td>
<td>723Kbps</td>
<td>110Mbps-1.6Gbps</td>
<td>11-105Mbps</td>
<td>10-250Kbps</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td>10-70 m</td>
<td>10m</td>
<td>4-20m</td>
<td>10-100m</td>
<td>10-70m</td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td>Very Low</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>Very Low-Low</td>
</tr>
<tr>
<td><strong>Battery Operation</strong></td>
<td>Alkaline (m-y)</td>
<td>Rechargeable (d-w)</td>
<td>Rechargeable (h-d)</td>
<td>Rechargeable (h)</td>
<td>Alkaline (m-y)</td>
</tr>
<tr>
<td><strong>Nodes</strong></td>
<td>65000</td>
<td>8</td>
<td>128</td>
<td>32</td>
<td>100-1000</td>
</tr>
</tbody>
</table>
# Wireless Technologies - Comparisons

<table>
<thead>
<tr>
<th>Feature</th>
<th>ZigBee</th>
<th>SP100</th>
<th>WirelessHART</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Market</strong></td>
<td>Consumer and Commercial</td>
<td>Industrial</td>
<td>Industrial</td>
</tr>
<tr>
<td><strong>Applications</strong></td>
<td>Smart Energy, Building Automation</td>
<td>Process Control Factory Automation</td>
<td>Industrial Control</td>
</tr>
<tr>
<td><strong>802.15.4</strong></td>
<td>2003</td>
<td>2006</td>
<td>2006</td>
</tr>
<tr>
<td><strong>Battery Operation Life</strong></td>
<td>+++</td>
<td>+++</td>
<td>++</td>
</tr>
<tr>
<td><strong>Device Type</strong></td>
<td>FFD, RFD</td>
<td>FFD, RFD</td>
<td>FFD</td>
</tr>
<tr>
<td><strong>Topology</strong></td>
<td>Mesh, Tree</td>
<td>Mesh, Tree</td>
<td>Mesh</td>
</tr>
<tr>
<td><strong>Channel Hopping/Agility</strong></td>
<td>Agility - Specifications 2007</td>
<td>Hopping</td>
<td>Hopping</td>
</tr>
<tr>
<td><strong>Sleeping Routers</strong></td>
<td>No. TBA in future specifications</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Latency</strong></td>
<td>4ms</td>
<td>10ms</td>
<td>10ms</td>
</tr>
<tr>
<td><strong>Preferred Channels-Channel Blacklist</strong></td>
<td>Preferred channel</td>
<td>Blacklist</td>
<td>Blacklist</td>
</tr>
<tr>
<td><strong>Encryption</strong></td>
<td>AES128</td>
<td>AES128</td>
<td>AES128</td>
</tr>
<tr>
<td><strong>Key Exchange</strong></td>
<td>Profile</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td><strong>Message Priority (QOS)</strong></td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Certification Program</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
## Wireless Technologies - Comparisons

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZigBee</td>
<td>General market appeal, lots of backing in Smart Energy space, products in market today</td>
<td>Not cost effective for high volume consumers, complex, not industrial grade</td>
</tr>
<tr>
<td>SP100.11a</td>
<td>Deterministic, immune to multipath, sleeping routers, CSMA and TDMA tunable, multiple fieldbus support, IPv6 support</td>
<td>Costly components required, object structure in the application layers adds structure which might be viewed by developers as restrictive</td>
</tr>
<tr>
<td>WirelessHART</td>
<td>Deterministic, immune to multipath, sleeping routers, existing wired devices in market</td>
<td>Costly components required, TDMA mode only</td>
</tr>
</tbody>
</table>
Wireless Sensor Networks Stack

- **Stack**: Layered, abstract description for network protocol design
- **Layer**: Collection of related functions, provides services to the layer above it, receives service from the layer below it.

Diagram:
- Application Layer
- Network Layer
- Medium Access Control Layer
- IEEE 802.15.4 Physical Layer
- Physical Medium
Stack Configuration

- **Physical Layer**
  - Controls the physical RF transceiver
  - Performs frequency and channel selection
  - Provides means for transmitting raw data bits (not packets)

- **IEEE 802.15.4 Physical Layer**

- **Medium Access Control Layer**

- **Network Layer**

- **Application Layer**

- **Physical Medium**
Stack Configuration

- **Medium Access Control (MAC) Layer**
  - Handles access to the physical radio channel
  - Manages radio synchronization
  - Provides reliable link between two peer MAC entities

- **Application Layer**
- **Network Layer**
- **Medium Access Control Layer**
- **IEEE 802.15.4 Physical Layer**
- **Physical Medium**
Network Layer
- Responsible for joining and leaving the network
- Routes frames to their destination
- Discovers and maintains routing tables
Stack Configuration

- **Application Layer**
  - Provides services to user-defined application processes, not to end-users
  - Handles fragmentation and reassembly of data packets
  - Defines the role of the device within the network
    - Coordinator, router or end-device

- **Network Layer**

- **Medium Access Control Layer**

- **IEEE 802.15.4 Physical Layer**

**Physical Medium**
IEEE 802.15.4

- Defines Physical (PHY) and Medium Access Control (MAC) layer
  - The Network and Application layers outside the scope of the standard

- Available frequencies
  - 868/915 MHz (20-40kbit/s)
  - 2.4 GHz (250kbit/s)

- Low power consumption

- Reliable MAC layer
  - Error checking
  - ACK based retransmissions
IEEE 802.15.4

- Full Function Device
  - PAN Coordinator
  - Router
  - Sensor
- Reduced Function Device
  - Sensor

Mesh

Cluster Tree

Star

PAN coordinator
Full Function Device
Reduced Function Device
ZigBee

- Defines Network and Application layer for IEEE 802.15.4 WSN
- Typical Applications
  - Consumer
  - Wireless keyboard/mouse and remote controls
  - Home Automation
  - Light-switch
  - Temperature monitoring automatic heating control
- Weaknesses
  - Static channels
  - Susceptible to background noise and RF interference
  - Not robust enough for industrial applications in harsh RF environments
- ZigBee PRO
  - ZigBee version aimed at the industrial market
  - "Frequency agility" – may change channels when faced with noise/interference
WirelessHART

- Part of HART Field communication Specification, Revision 7.0
  - Released Sept. 2007
  - Allows for wireless transmission of HART messages
- Based on IEEE 802.15.4 PHY with modified MAC Layer
- Full mesh network topology
- Adaptive frequency hopping
- Time-division multiple access (TDMA)
ISA100.11a

- ISA100
  - Family of wireless standards for industrial automation
  - WSN, WLAN, WiMAX

- ISA100.11a
  - Wireless non-critical monitoring and control applications
  - Uses IEEE 802.15.4 PHY and modified MAC
  - Frequency hopping
  - Star-mesh network
  - Capable of transferring multiple wired protocols
    - 4-20ma, Ethernet, HART, FF, Modbus
  - Expected ratified
6LoWPAN

- Provides open-systems based interoperability among low power devices over IEEE 802.15.46. Turns IEEE 802.15.4 into the IP enabled link
- Orthogonal stackable header format
  - Almost no overhead for the ability to interoperate and scale.
  - Coexistence with other network protocols over same link
  - Header dispatch - understand what’s coming
- IPv6 address <prefix64 interface id> for nodes in 802.15.4 subnet derived from the link address.
  - PAN ID maps to a unique IPv6 prefix
  - Interface identifier generated from EUID64 or Pan ID and short address
  - Hop Limit is the only incompressible IPv6 header field
- Appropriate for WSN that have resource constraints of low power, low memory, low bandwidth devices.
WiBree forum merged with Bluetooth SIG to become part of the Bluetooth specification. WiBree rounds out BT technology PAN. Ultra low power BT two implementation options:

- Stand-alone implementation
- Dual-mode implementation (extension to Bluetooth radio)

<table>
<thead>
<tr>
<th>Technology</th>
<th>Bandwidth</th>
<th>Range</th>
<th>Power</th>
<th>Frequency band</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bluetooth 2.0</td>
<td>2.1 Mbit/s</td>
<td>0.01-100m</td>
<td>Low</td>
<td>2.4 GHz</td>
</tr>
<tr>
<td>Wibree</td>
<td>1 Mbit/s</td>
<td>10 m</td>
<td>Very Low</td>
<td>2.4 GHz</td>
</tr>
<tr>
<td>ZigBee</td>
<td>250, 40, 20 Kbit/s</td>
<td>10 -75 m</td>
<td>Very Low</td>
<td>2400, 915, 868 MHz</td>
</tr>
<tr>
<td>WirelessHD</td>
<td>2 -20 Gbit/s</td>
<td>10 m</td>
<td>Very High</td>
<td>60 GHz</td>
</tr>
<tr>
<td>Certif. Wireless USB</td>
<td>480 Mbit/s</td>
<td>10 m</td>
<td>Medium</td>
<td>3.1 -10.6 GHz</td>
</tr>
<tr>
<td>WirelessUSB</td>
<td>1 Mbit/s -62.5 Kbit/s</td>
<td>10 -50 m</td>
<td>Low</td>
<td>2.4 GHz</td>
</tr>
<tr>
<td>Wi-Fi IEEE 802.11n</td>
<td>540 Mbit/s</td>
<td>50 m</td>
<td>High</td>
<td>2.4 GHz or 5.8 GHz</td>
</tr>
<tr>
<td>Fixed WiMAX</td>
<td>75 Mbit/s</td>
<td>1 -50 km</td>
<td>Medium</td>
<td>3.5, 5 GHz (in Europe)</td>
</tr>
<tr>
<td>Mobile WiMAX</td>
<td>30 Mbit/s</td>
<td>2 -5 km</td>
<td>Medium</td>
<td>3.5, 5 GHz (in Europe)</td>
</tr>
<tr>
<td>HSDPA</td>
<td>14.4 -1.8 Mbit/s</td>
<td>0.1-20 km</td>
<td>Medium</td>
<td>1900-1920 &amp; 2010-2025 MHz</td>
</tr>
</tbody>
</table>

Enhances the current BT use cases around personal devices (e.g. mobile phones)
Seamless connectivity with very LP sensor devices
UWB

- High data rates are possible
  - 500+ Mbps achievable at short ranges (i.e., < 3 meters) under current regulations
  - Data rate scales with ever faster CMOS circuits
- Low power compatible with CMOS
  - Suitable for battery-operated devices
- Position and Location capabilities
- Key elements and challenges
  - FLEXIBLE - provide variable spectral filling of the wideband channel and better co-existence
  - SCALABLE - scale performance with technology advancement
  - ADAPTABLE - accommodate potentially different worldwide regulations
  - LOW COST - enable full CMOS integration
  - WORLDWIDE STANDARD – provide a single, common physical layer to meet broad industry requirements
- IEEE 802.15.3a (TBR - to be ratified)
RuBee IEEE P1902.1

- 131 KHz TCP/IP IPv6 Protocol IEEE P1902.1 – Pending
- RuBee is a bi-directional, low power wireless peer to peer protocol (LF) based on magnetic field. Signals are unaffected by steel or water and could be appropriate for placing tags in metal objects.
- User memory capacity required is recommended to be minimum 2048 bits. The ID number of bits recommended is minimum 96 bits.

<table>
<thead>
<tr>
<th>Standard</th>
<th>RuBee P1902.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data</td>
<td>5kbs</td>
</tr>
<tr>
<td>Battery Operation Life</td>
<td>4000 days</td>
</tr>
<tr>
<td>Bandwidth kbps</td>
<td>1 + Clip</td>
</tr>
<tr>
<td>Net Size</td>
<td>No Limit</td>
</tr>
<tr>
<td>Range m</td>
<td>1-30</td>
</tr>
<tr>
<td>Security</td>
<td>High</td>
</tr>
</tbody>
</table>
RFID Tags - Complex Smart Systems

- Many alternatives in terms of design and assembly
- Several components and suppliers
  - ICs (SoC)
  - Sensors
  - Batteries, power generation
  - Energy harvesting
  - Inlays & labels
  - Antenna design & printing
Smart Wireless Systems

Beyond RF ID - Functionality
- Multi Antennas
  - On Chip Antenna – OCA
  - Coil on Chip (HF)
  - Printed antennas
  - Embedded antennas
  - Multiple antenna substrates
  - 3D structures

Integrated Circuit
- Micro/Nanoelectronics/Polymer
  - Multi RF Front Ends
    - HF/UHF/MW/Radar
  - Memory – EEPROM/FRAM/Polymer
  - ID 128 bits + other type ID
  - Multi Communication Protocols
  - UWB
  - Digital Processing
  - Security

Displays
- Bi-stable
- Flexible
- Transparent

Sensors/Actuators
- MEMS/NEMS
- Sensors on Chip
- Molecular sensors

Assembly

Power Generation
- RF
- Solar
- Harvesting (vibration, temp, etc.)
- Batteries printed/polymer
- Fuel cells

Source: Siemens

Combined flexible contact lens with an imprinted electronic circuit

Source: University of Washington

Source: Toshiba
Challenges and Constraints

- **Semiconductor technology scaling gives rise to three key challenges:**
  - Challenge of scalability
    - the need to extend communications and processing to large data, over heterogeneous channels
  - Challenge of adaptation
    - the need to reuse and retarget both hardware and software
  - Challenge of integration
    - the need to more optimally exploit heterogeneous component technologies with respect to cost, performance, energy tradeoffs

- **Fundamental technology constraints:**
  - Energy (limitations of batteries, sensors)
  - Bandwidth (limited speed of semiconductor devices)
  - Non-scalability of analog circuits
  - Scaling of on- and off-chip interconnects
Challenges and Constraints

- **On-chip intelligence**
  - FSM, micro-programmed logic, microcontroller
  - Wider programmability implies higher power consumption

- **Embedded memory**
  - Higher capacity, higher die size and power consumption

- **Embedded sensors**
  - Higher design complexity
  - Easier assembly phase
  - Smaller tag cost
Smart Integrated Systems

Performance Complexity

Class 0
- Basic Functions
  - Identification

Class 1
- 1st Generation
  - EPC RFID Devices

Class 2
- 2nd Generation
  - EPC RFID Devices

Class 3
- 3rd Generation
  - Sensing RFID Devices

Class 4
- 4th Generation
  - Acting RFID Devices

Class 5
- 5th Generation
  - Interacting RFID Devices

Linking WEB and the real world by RFID Sensor Networks "Internet of Things"

RFID Technology Research and Development:
- Multi band RFID, multi protocol RFID, on chip antenna, sensor/actuator integration, energy generation
Architecture

 RFID Hardware

Tag ID Provider
Tag ID Assigned by Provider

RFID Tag
Standard
Frequency

Tag ID

Sensor Data
Antenna
Reader

Unprocessed Tag Data

Middleware

Visibility Manager
Tag data in XML Files
Parsed Tag Data
Temporary Flat Files

Web based Management
Enterprise Resource Planning (ERP)

RFID Database Repository
Tag Data

Database Loader

Parsed Tag Data

XML Parser

Applications

Server
User Displays
Real virtual and digital worlds

Bridging the real, virtual and digital worlds by using wireless connectivity.

Source: University of Tokyo - Virtual-reality system
Real virtual and digital worlds

- Connecting real, virtual and digital worlds
- The challenge:
  - Linking smart wireless identifiable devices and RFID data with virtual worlds software programs
- Transfer positions of real persons and real things into the virtual world.
- Enable the smart wireless devices to trigger actions in the real world.

“Connecting virtual reality with real world commerce"

Residents can go to the virtual factory, customize their Dell and purchase, and their PC arrives at their real-life door.

Source: Dell
Real virtual and digital worlds

- Physical world embedded with:
  - RFID, smart wireless identifiable devices, novel materials, processing units.
  - MEMS, NEMS, micro/nano robots, computational particles
  - Wired and wireless networks

- Ubiquitous smart/intelligent things/objects
  - Things capable of computing and communicating
  - Things able to be connected to everything
  - Smart things behaving with certain “intelligence”

Ubiquitous intelligence
Being a ubiquitous existence
Residing in everyday objects, environments, etc.
Man-made and natural things
# Wireless identifiable devices and RFID

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Application Layer</strong></td>
<td>Data interpretation Application software, diagnosis</td>
</tr>
<tr>
<td><strong>Algorithmic Layer</strong></td>
<td>Algorithms for data interpretation Pattern matching, sensor data fusion, classification</td>
</tr>
<tr>
<td><strong>Processing Layer</strong></td>
<td>Digital signal processing Sensor data calibration, data correction, compression, feedback and control loop</td>
</tr>
<tr>
<td><strong>Interfacing Layer</strong></td>
<td>Interface between sensor and signal processing unit ADC, DAC, counter, pulse generator</td>
</tr>
<tr>
<td><strong>Signal Conditioning Layer</strong></td>
<td>Signal conditioning Amplification, buffering, actuator driving, analog electronics</td>
</tr>
<tr>
<td><strong>Physical Layer</strong></td>
<td>Physical sensing or actuating mechanism Transducer design and physics, device physics inside circuit, MEMS, sensors,</td>
</tr>
<tr>
<td><strong>Technology Layer</strong></td>
<td>Circuits and sensor technology MEMS, CMOS, nanotechnology, micro-optics</td>
</tr>
</tbody>
</table>
Wireless identifiable devices and RFID

- RFBlock 18000-6c
  - ID
- Logic Processing

- Memory PROM ID
- Security

- RFBlock Standard ID
- Memory EEPROM ID
  - User
- Data Interface I/O
- Logic Processing

- Network Connection Reader Tag
- Security

- RFBlock Multi Standard
- Storage Memory EEPROM EPC
- Analog Digital Interface

- Data Interface SPI/I²C
- µController Data Processing
- Sensors MEMS Actuators

- Power Management
- Battery/Energy Harvesting

- Network Connection
- Security

- RFBlock ID
- Storage Memory EEPROM ID
- Analog Digital Interface

- Data Interface SPI/I²C
- µController Data Processing
- Sensors MEMS Actuators

- Power Management
- Battery/Energy Harvesting
Multi standard and sensing RFID

- 2 Standards
- HF/UHF
- Sensing

Mixed Signal Interface
RFID Mixed Signal Sensor Interface

- Ultra low power: < 8μA for less than 400ns
- Low voltage operation: 1-1.2V

- Capacitive to Voltage Converter
- Current Reference
- Analog to Digital Converter
Wireless Smart System Applications

- Automotives
- Aeronautics
- Information and Telecommunication (ITC)
- Medical Technologies
- Logistics and object mobility and management

Chrysler
Real virtual and digital home

SMART HOME Intel expects a wireless network of sensors, called motes, to help older people live on their own longer. The motes pass information among themselves and to a PC. The data they gather is analyzed to infer activities of daily living, which can give important clues to a person’s state of health and allow for intervention.

- Motes in shoes and other clothing tell the system what a person is wearing. If he’s getting dressed to go for a walk, the system might inform his walking partner that he is ready to go.
- A mote on a pill bottle scale can tell whether a person took her medication.
- Motes monitor a person’s bathroom use.
- Motes on the dishwasher tell how often it is run, indicating how many meals the person has eaten.
- Motes on cups can tell if they have been taken out of the cabinet.
- Motes in the bed tell if there is anyone lying in it.
- A PC synthesizes data from the motes to form a picture of what is going on in the house.

The computer can send messages to TV sets and displays in the house to assist people suffering from dementia with their daily tasks.

Source: Intel
RFID in the Office and Buildings

- Sensor data collection
- Exploit moving nodes
- Exploit network coding for efficiency

Intelligent Buildings
- RFID Integration
Real virtual and digital car

- RFID derived position among vehicles (V2V)
- RFID for communication between the vehicle and infrastructure (V2I and I2V),
- LANE LEVEL position

Vehicle Identification System

- Determine if a vehicle registration has expired.
- Monitor traffic and vehicle speed in construction zones or other pertinent areas.
- Ticketing parking.

http://www.compexinc.com/
WSN RFID in Oil and Gas Industry

- Wireless instrumentation for
  - Installations in remote and hostile areas
  - Temporary installations
  - Ease of scalability
  - Redundant data collection for production optimization

- RFID and WSN for
  - Personnel
  - Equipment
  - Containers
  - Drilling tools
  - Monitoring
  - Maintenance

Source: StatoilHydro
Roads Bridges and RFID

- Strain Sensing System Using 13.56MHz passive-type Sensor-Integrated RFID.
- The system, measures the changes and deformation caused by various types of deterioration and loading on the structure, without using a battery.
- Embedded RFID sensor that is integrated within the concrete.
- Measurements at a strain resolution level of approximately 10X10^-6.
- Using a thermistor, the system simultaneously measures temperature and can account for deformation caused by temperature.

Efficient maintenance and management of roads, bridges and public housing. Concrete and steel structures monitoring due to everyday traffic, wind and earth pressure and earthquakes.
Real virtual and digital healthcare

- Mobile cardiac telemetry monitoring platform
- 24/7/365 patient freedom to go anywhere at anytime

Source: CARDIONET
Real Time Location Systems

- Intelligent long range active RFID systems to identify, locate and track assets at a distance of up to 100m and to deliver superior real time visibility in dynamic, demanding environments.
- Long range (100m) RFID tag not with read/write capability, and 360° visibility of wireless regardless of tag orientation.

- Features:
  - Sensor location layout map
  - Planned number of readers and access point antennas
  - Placement of active RFID Tags on the assets.
Distributed RFID and Wireless Smart Sensor Systems

- RFID Sensors
- Wireless communication
- Electronics and Systems Integration
- Information Technologies
- Systems Engineering,
- Maintenance technologies

- Sensor data collection
- Exploit moving nodes
- Exploit network coding for efficiency
- RFID Integration

- Wireless devices
- Cockpit displays
- Computer
- Ethernet
- Passive RFID
- Wireless LAN
- Multi hop Mesh
- Smart Sensor
- Sensor Network
- Smart RFID Sensor
THE LATEST ENVIRONMENTAL CRISIS: WIRELESS DATA POLLUTION.