IoT deployment in SRD networks

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IoT most relevant activities to WP 5A

1. RLAN (Wi-Fi; IEEE 802.11) connecting IoT
2. Wide-area sensor and/or actuator network (WASN) systems supporting M2M:
   Q. 250-1/5; Rec. M.2002; Rep. M.2224
3. Characteristics and examples:
   1) Ultra-narrowband UNB, Narrowband, Wideband (broadband)
   2) Long range (LoRaWAN, SigFox, Weightness, Ingenu ...)
   3) Short range (BTLE, IEEE 802.11ah, IEEE 802.15.4, DECT, ZigBee, Z-wave ...)

The full presentation appears at the ITU WEB; I won’t present all slides
SRDs and IOT

‘The Internet changed our lives, and the Internet of Things will change us again’ Jason Hiner

1. Machine to Machine (M2M) interconnect via licensed mobile systems (such as cellular and PMR) or via unlicensed infrastructure of Short Range Devices (SRDs)

2. RLAN (Wi-Fi) and other SRDs (such as Bluetooth, Zigbee, Wi-SUN, Z-WAVE) may connect IoT to wireless networking

3. Do we need a specific or additional RF band dedicated to IoT at the RF SRD RF bands?
Frequency Bands for SRDs

Global

- 9-148.5 kHz; 3,155-3,400 kHz
- 9 kHz-47 MHz (specific SRDs)
- 7,400-8,800 kHz
- 138.20-138.45 MHz
- 169.4-216 MHz
- 312-315 MHz (non Europe)
- 402-405 MHz medical devices
- 470-489 MHz (normally individually licensed)
- 823-832 MHz and 1,785-1,805 MHz
- 862-875 MHz in some Asian counties
- 862-876 MHz Non-Specific SRDs
- 915-921 MHz (in some countries)
- 5,150-5,350 & 5,470-5,725 MHz
- 57-64 GHz, 76-77 GHz, 77-81 GHz

Only in Europe

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Only in Americas

- 57-81 GHz

ISM bands

- 6,780 kHz; 13,560 kHz
- 27,120 kHz; 40.68 MHz
- 433.92 MHz
- 915 MHz
- 2,450 MHz; 5,800 MHz
- 24.125 GHz; 61.25 GHz
- 122.5 GHz; 245 GHz

Non-ISM candidate bands for SRDs

- 5,150-5,350 & 5,470-5,725 MHz
- 57-64 GHz, 76-77 GHz, 77-81 GHz

Fig 3.1; Mazar’s Wiley book 2016
1. **Resolution 958 (WRC-15), Annex item 3 and WRC-19 Agenda Item 9.1 (issue 9.1.8)** ‘Studies on the technical and operational aspects of radio networks and systems, as well as spectrum needed, including possible harmonized use of spectrum to support the implementation of narrowband and broadband machine-type communication infrastructures’

2. In addition to mobile systems (such as GSM), without prejudging WRC-19 results, the present SRD’s RF bands, shown at previous slide, may provide to IoT the necessary coverage and capacity for narrow and wideband, in narrow and wide area
Wi-Fi, RLAN, WLAN, U-NII (Unlicensed-National Information Infrastructure) operating in 5.15-5.35 GHz and 5.470-5.85 GHz)

Unrelated to IoT, for me personally, when abroad, connected to RLAN is more important than cellular connection, to offer free internet connection and audio/video calls
<table>
<thead>
<tr>
<th>Characteristics</th>
<th>IEEE Std 802.11-2012 (Clause 17, commonly known as 802.11b)</th>
<th>IEEE Std 802.11-2012 (Clause 18, commonly known as 802.11a)</th>
<th>IEEE Std 802.11-2012 (Clause 19, Annex D and Annex E, commonly known as 802.11g)</th>
<th>IEEE Std 802.11-2012 (Clause 20, commonly known as 802.11n)</th>
<th>IEEE Std 802.11ad-2012</th>
<th>IEEE Std 802.11ad-2012</th>
<th>ETSI EN 300 328</th>
<th>ETSI EN 301 893</th>
<th>ARIB HiSWANa</th>
<th>ETSI EN 302 567</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frequency band</strong></td>
<td>2 400-2 483 MHz</td>
<td>150-5 250 MHz</td>
<td>2 400-2 483.5 MHz</td>
<td>2 400-2 483.5 MHz</td>
<td>5 150-5 250 MHz</td>
<td>5 150-5 250 MHz</td>
<td>5 150-5 250 MHz</td>
<td>5 150-5 250 MHz</td>
<td>5 150-5 250 MHz</td>
<td>5 150-5 250 MHz</td>
</tr>
<tr>
<td><strong>Interference mitigation</strong></td>
<td>LBT</td>
<td>LBT/DFS/TPC</td>
<td>LBT</td>
<td>LBT/DFS/TPC</td>
<td>LBT/DFS/TPC</td>
<td>LBT</td>
<td>DAA/LBT, DAA/non-LBT, MU</td>
<td>LBT/DFS/TPC</td>
<td>LBT</td>
<td></td>
</tr>
<tr>
<td><strong>Channel indexing</strong></td>
<td>5 MHz</td>
<td>5 MHz in 2.4 GHz</td>
<td>20 MHz</td>
<td>2 160 MHz</td>
<td>20 MHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note: All frequency bands are in MHz.*
## Major 802.11 (Wi-Fi) Standards

<table>
<thead>
<tr>
<th></th>
<th>802.11a</th>
<th>802.11b</th>
<th>802.11g</th>
<th>802.11n</th>
<th>802.11ad^</th>
<th>802.11ac*</th>
<th>802.11af**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum data rate (Mbps)</td>
<td>54</td>
<td>11</td>
<td>54</td>
<td>&lt; 600</td>
<td>&lt;7 Gbps</td>
<td>&lt; 600***</td>
<td></td>
</tr>
<tr>
<td>Modulation</td>
<td>OFDM</td>
<td>CCK or DSSS</td>
<td>CCK, DSSS, or OFDM</td>
<td>SC and OFDM</td>
<td>OFDM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RF Band (GHz)</td>
<td>5</td>
<td>2.4</td>
<td>2.4 or 5</td>
<td>60</td>
<td>5</td>
<td>TV bands below 1 GHz</td>
<td></td>
</tr>
<tr>
<td>Number of spatial streams</td>
<td>1</td>
<td>1 to 4</td>
<td>5 to 8</td>
<td>1,2,3,4 or 8</td>
<td>up to four streams</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Channel width (MHz) nominal</td>
<td>20</td>
<td>20 or 40</td>
<td>80 or 160</td>
<td>20, 40, 80, 160</td>
<td>8 in Europe; 6 in N. America</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### WLAN: IEEE 802.11 Network bearer standards

- **^** known also as µwave Wi-Fi; brand name WiGig operating in the 2.4, 5 and 60 GHz bands
- **^** known also as Gigabit Wi-Fi, 5G Wi-Fi and 5G very high throughput (VHT)
- **^** known also as White-Fi and Super Wi-Fi
- **^** max data rate is 426.7 Mbit/s in 6 & 7 MHz channels, & 568.9 Mbit/s for 8 MHz channels

Source: also Radio-Electronics.com

ITU Workshop on Spectrum Management for Internet of Things Deployment, 22 November 2016, Geneva
1. Wide-area sensor and/or actuator network (WASN) systems supporting M2M

2. Mobile wireless access system is a large cell-based public network that can provide telecommunications to various objects including M2M services with wide area coverage

3. Large cell-based wireless access system with cell radius of about several to 10 km supports rural as well as urban areas
sensors or actuators: transmission rate & density supported by WASN systems

Fig. 1 Rec. ITU-R M.2002

Objectives, characteristics & functional requirements of WASN systems

System transmission rate (bps)

- Sensor data / control signal
- Voice
- Video
- HDTV

Density of wireless terminals (/km²)

Urban

10 000 000

1 000 000

100 000

10 000

1 000

10

Rural

Uninhabited

1 K 10 K 100 K 1 M 10 M 100 M 1 G

10

100

1 000

10 000

100 000

1 000 000

10 000 000
### Main system parameters of VHF-band WASN

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RF</strong></td>
<td>Higher portion of VHF bands</td>
<td>280 MHz was licensed in Japan for experimental purposes only.</td>
</tr>
<tr>
<td><strong>Modulation rate</strong></td>
<td>Downlink: 9 600 baud</td>
<td>Modulation rate of 9 600 baud is considered the basic design of the system.</td>
</tr>
<tr>
<td></td>
<td>Uplink: 9 600 baud</td>
<td></td>
</tr>
<tr>
<td>(option)</td>
<td>Uplink: 4 800, 2 400, 1 200, 600 baud</td>
<td>The uplink modulation rate is switched from 9 600 to 4 800, 2 400, 1 200 and 600 baud in order to increase link margins in metropolitan areas.</td>
</tr>
<tr>
<td><strong>Transmission power</strong></td>
<td>WT: 10 dBm</td>
<td>The transmission power of WTs is defined as 10 dBm, assuming a low-power data communication system. BS transmission power is set to up to 36 dBm considering the man-made noise at WTs or the link margins in downlink.</td>
</tr>
<tr>
<td></td>
<td>BS: up to 36 dBm</td>
<td></td>
</tr>
<tr>
<td>(option)</td>
<td>WT: up to 30 dBm</td>
<td>The transmission power of WTs can be increased to increase link margins in metropolitan areas. The transmission power of WTs and BS can be adjusted for radio link design according to supported area or applications.</td>
</tr>
<tr>
<td><strong>Multiple access method</strong></td>
<td>TDMA</td>
<td>To accommodate a large number of WTs, TDMA is applied as the multiple access method. TDMA allows BS to flexibly control or assign bandwidth via a centralized control.</td>
</tr>
<tr>
<td><strong>Duplexing method</strong></td>
<td>TDD</td>
<td>TDD is applied as the duplexing method because two-way single-band transmission and open-loop transmission power control are available.</td>
</tr>
<tr>
<td><strong>Modulation method</strong></td>
<td>Downlink: ( \frac{\pi}{2} )-shift; BPSK (signal); ( \frac{\pi}{4} )-shift QPSK (data); Uplink: ( \frac{\pi}{4} )-shift QPSK</td>
<td>For control signal transmission in downlink, ( \frac{\pi}{2} )-shift BPSK is applied for robust operation of the system. For data transmission, ( \frac{\pi}{4} )-shift QPSK is applied as the modulation method due to its spectral efficiency.</td>
</tr>
<tr>
<td>(option)</td>
<td>Downlink: 16QAM (data)</td>
<td>In addition to the parameters of the basic type, 16QAM is defined as an option for network management by multicast signal control in downlink.</td>
</tr>
<tr>
<td><strong>Detection method</strong></td>
<td>Downlink:Differential detection; Uplink: Coherent detection</td>
<td>On the WT side, differential detection is applied as a signal detection method, where frequency offset diversity can be applied. On the BS side, coherent detection is applied.</td>
</tr>
<tr>
<td><strong>Forward error correction and interleaving</strong></td>
<td>Convolutional coding and Viterbi decoding</td>
<td>To avoid transmission quality deterioration caused by fading and to improve the communication range, forward error correction is applied using convolutional coding and Viterbi decoding. In addition, bit interleaving on the temporal axis is applied to avoid burst errors caused by fading.</td>
</tr>
<tr>
<td><strong>Tx power control (TPC)</strong></td>
<td>Open-loop TPC</td>
<td>In uplink transmission, a simple open-loop TPC is applied to ensure a large reception dynamic range and to avoid the distance problem of the WTs in adjacent RF channels</td>
</tr>
<tr>
<td><strong>Diversity method</strong></td>
<td>Space and site diversity Uplink: MRC Downlink: RF offset</td>
<td>The system assumes that each WT has a single antenna and that an BS has multiple antennas. Thus, the diversity techniques of a multi-to-single antenna configuration in the downlink and a single-to-multi antenna one in the uplink are applied. In addition, space and site diversity techniques are combined to improve the diversity effect.</td>
</tr>
</tbody>
</table>
Fig 1: Report ITU-R M.2224

System design guidelines for WASN systems

AS Application server
BS Base station
DB Database
GW Gateway
RN-GW Radio network gateway
RS Relay station
UNI User-network interface
UT User terminal
WASN Wide area sensors and/or actuators network
WN-GW Wired network gateway
WT Wireless terminal
WT-MS WT management server

Wireless network
WASN cell configuration

Figures 3, 4, 5: Report ITU-R M.2224

cluster size of 7

cluster size of 16

3-sector antenna

ITU Workshop on Spectrum Management for Internet of Things Deployment, 22 November 2016, Geneva
WASN, home energy consumption

Fig 8: Report ITU-R M.2224
Planning tool simulating IoT application (LoRa), to cover entire city.

LoRa Gateway 43m AGL building; installed roof-top;
Down Link: RF 920 MHz MHz; 500mW ERP
Rx Threshold: -116dBm; 3m AGL outdoor+indoor
Typical Smart House: Z-Wave

- Designed mainly for remote controls, smoke alarms, and security sensors.
- Z-Wave uses a single frequency FSK.
- Data rate up to 100 Kbps; unlike IEEE 802.11, designed primarily for high-bandwidth data flow.
- Range between controllers & slave devices up to 100 ft.

<table>
<thead>
<tr>
<th>Country/Region</th>
<th>Standard</th>
<th>Z-Wave RF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>AS/NZS 4268</td>
<td>921.4 MHz</td>
</tr>
<tr>
<td>Brazil</td>
<td>ANATEL Resolution 506</td>
<td>921.4 MHz</td>
</tr>
<tr>
<td>CEPT</td>
<td>EN 300 220</td>
<td>868.4 MHz</td>
</tr>
<tr>
<td>Chile</td>
<td>FCC CFR47 Part 15.249</td>
<td>908.4 MHz</td>
</tr>
<tr>
<td>China</td>
<td>CNAS/EN 300 220</td>
<td>868.4 MHz</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>HKTA 1035</td>
<td>919.8 MHz</td>
</tr>
<tr>
<td>India</td>
<td>CSR 564 (E)</td>
<td>865.2 MHz</td>
</tr>
<tr>
<td>Israel</td>
<td>MoC Wireless Act</td>
<td>915-917 MHz</td>
</tr>
<tr>
<td>Japan 950</td>
<td>ARIB T96</td>
<td>951-956 MHz</td>
</tr>
<tr>
<td>Japan 920</td>
<td>ARIB STD-T108</td>
<td>922-926 MHz</td>
</tr>
<tr>
<td>Malaysia</td>
<td>SKMM WTS SRD/EN 300 220</td>
<td>868.1 MHz</td>
</tr>
<tr>
<td>Mexico</td>
<td>FCC CFR47 Part 15.249</td>
<td>908.4 MHz</td>
</tr>
<tr>
<td>New Zealand</td>
<td>AS/NZS 4268</td>
<td>921.4 MHz</td>
</tr>
<tr>
<td>Russia</td>
<td>GKRCh/EN 300 220</td>
<td>869.0 MHz</td>
</tr>
<tr>
<td>Singapore</td>
<td>TS SRD/EN 300 220</td>
<td>868.4 MHz</td>
</tr>
<tr>
<td>South Africa</td>
<td>ICASA/EN 300 220</td>
<td>868.4 MHz</td>
</tr>
<tr>
<td>Taiwan</td>
<td>NCC/LP0002</td>
<td>922-926 MHz</td>
</tr>
<tr>
<td>UAE</td>
<td>EN 300 220</td>
<td>868.4 MHz</td>
</tr>
<tr>
<td>USA/Canada</td>
<td>FCC CFR47 Part 15.249</td>
<td>908.4 MHz</td>
</tr>
</tbody>
</table>
1. International, regional & national regulation of SRDs at ITU Workshop on SRDs, Geneva 3 June 14

2. International, Regional and National regulation of Electronic Devices and SRD’s at Telecommunication Certification Body, Council, 15 April15, Baltimore MD; US


Any Questions?