Agenda

- IoT/M2M Introduction and Market Situation
  - What is IoT?
  - Wireless technologies in IoT

- IoT/M2M Key Enabling Technologies
  - WLAN 802.11ah and 802.11p
  - Bluetooth Low Energy
  - ZigBee (802.15.4) and Wi-SUN (802.15.4g)
  - NFC

- IoT/M2M Test Solution
  - Bench-top solution for R&D
  - One-box test or low cost solution for manufacturing
What is IoT?

Internet of Things

- Brings together M2M technology with Big Data and Machine Learning

- The Internet of Things (IoT) is the network of physical objects or "things" embedded with electronics, software, sensors and connectivity to enable it to achieve greater value and service by exchanging data with the manufacturer, operator and/or other connected devices.
Primary IoT/M2M Markets

Key requirements: Power efficient, Scalable, Range Extended
Connecting “Things” to the Cloud

Cloud storage, intelligence & analytics

Industrial, vehicle, maritime, aviation gateways

Cable/fibre

Cellular

Low Power Wide Area

Satellite

e.g. LTE

Ethernet

e.g. LTE

Consumer gateways

e.g. THREAD, ZigBee, Z-Wave

Sensors and actuators

e.g. IoT/SUN

WiFi AP

WiFi

WiFi

WiFi

WiFi

Wi-Fi

Cellular

Ethernet

Satellite

Industrial, vehicle, maritime, aviation gateways

e.g. Wi-Fi

e.g. ZigBee

e.g. Wi-Fi

e.g. Wi-SUN

Bluetooth

NFC

Industrial, vehicle, maritime, aviation gateways

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## IoT Key Enabling Wireless Technologies Summary

<table>
<thead>
<tr>
<th>Standards</th>
<th>Freq(s)</th>
<th>Max BW</th>
<th>Data rate</th>
<th>Mod</th>
<th>Range</th>
<th>Network</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTE-M Category 0/1 (LTE Rel12/13)</td>
<td>LTE band</td>
<td>1.4 MHz</td>
<td>200 kbps ~ 1 Mbps</td>
<td>OFDM</td>
<td>1000 m</td>
<td>WMAN</td>
<td>lower speed and power versions of the LTE standard defined in Rel12/13</td>
</tr>
<tr>
<td>802.11ah (IEEE 802.11)</td>
<td>Sub GHz</td>
<td>1 to 16 MHz</td>
<td>150 kbps to 78 Mbps</td>
<td>OFDM</td>
<td>1000 m</td>
<td>WLAN</td>
<td>Target for IoT, wearable devices or extend range</td>
</tr>
<tr>
<td>802.11p (IEEE 802.11)</td>
<td>5.8~5.9 GHz</td>
<td>5/10/20 MHz</td>
<td>1.5 Mbps to 54 Mbps</td>
<td>OFDM</td>
<td>1000 m</td>
<td>WLAN</td>
<td>Wireless access in vehicle environment (WAVE)</td>
</tr>
<tr>
<td>Bluetooth Low Energy</td>
<td>2.4 GHz</td>
<td>2 MHz</td>
<td>1 Mbps</td>
<td>GFSK</td>
<td>50 m</td>
<td>WPAN</td>
<td>automotive, healthcare, security, home entertainment</td>
</tr>
<tr>
<td>Z-Wave (ITU G.9959)</td>
<td>868.42 MHz 908.42 MHz</td>
<td>200 kHz</td>
<td>9.6 kbps ~100 kbps</td>
<td>BFSK</td>
<td>100 m</td>
<td>WPAN</td>
<td>Remote controls, smoke alarm, security sensors Owned by Denmark Zensys</td>
</tr>
<tr>
<td>ZigBee (802.15.4)</td>
<td>ISM &lt; 2.4 GHz</td>
<td>5 MHz</td>
<td>40 kbps to 250 kbps</td>
<td>BPSK</td>
<td>10 m</td>
<td>WPAN</td>
<td>Home automation, smart grid, remote control</td>
</tr>
<tr>
<td>Thread (802.15.4)</td>
<td>ISM &lt; 2.4 GHz</td>
<td>5 MHz</td>
<td>40 kbps to 250 kbps</td>
<td>BPSK, FSK, OQPSK</td>
<td>10 m</td>
<td>WPAN</td>
<td>Mesh network for home and support 6LoWPAN</td>
</tr>
<tr>
<td>Wi-Sun (802.15.4g)</td>
<td>ISM &lt; 2.4 GHz</td>
<td>200 kHz to 1.2 MHz</td>
<td>50 kbps to 1 Mbps</td>
<td>FSK, OFDM, OQPSK</td>
<td>1000 m</td>
<td>WNAN</td>
<td>FAN and HAN Smart Utility Networks, Smart Grid, Smart Metering</td>
</tr>
<tr>
<td>NFC (ISO/IEC18092)</td>
<td>13.56 MHz</td>
<td>1 MHz</td>
<td>848 kbps</td>
<td>FSK, ASK</td>
<td>20 cm</td>
<td>P2P</td>
<td>Contactless payment, easy other connection (Wi-Fi, BT), identity and access</td>
</tr>
</tbody>
</table>
Agenda

- **IoT/M2M Introduction and Market Situation**
  - What is IoT?
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- **IoT/M2M Key Enabling Technologies**
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  - ZigBee (802.15.4) and Wi-SUN (802.15.4g)
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- **IoT/M2M Test Solution**
  - Bench-top solution for R&D
  - One-box test or low cost solution for Manufacturing
IoT Key Enabling Technologies

IEEE 802.11ah – Middle 2016

– IoT applications
  • IEEE 802.11ah PHY and MAC are specified for IoT type of applications
  • Envisioned to provide IP connectivity to all types of devices that are currently not connected to the internet and yet-to-be-invented devices

– Target use cases
  • Large scale sensor networks and meters
  • Extended range hotspot
  • Outdoor Wi-Fi for cellular traffic offloading

– Standards status:
  • The IEEE 802.11 WG is currently developing draft 4.0 of the spec, which typically means it is stable enough to commence WFA MRD activities
  • Targeted IEEE specification will be finalized in mid-2016
  • WFA has decided to create a Marketing Task Group to start the development of an interoperability program. Potential WFA program launch: H2 2016
802.11ah Global Channelization

From IEEE 802.11ah draft standard
802.11ah Use Case #1

Indoor Low Power Sensors

- Extended range
  - Reach garage, backyard, basement, attic
  - 1 MHz and 2 MHz mandatory modes
- Battery operated sensors
  - No power amplifiers
- Large numbers of devices (1000s) per AP
- Ultra-low power consumption
  - Optimized for small packet size
  - Multi-year battery life
  - Long sleep time
  - Burst traffic
- IP support
802.11ah Use Case #2
Backhaul Sensors and Meter Data

– Backhaul aggregation of smart grid meter data
– Backhaul aggregation of industrial sensor data
## PHY Differences between 802.11ac and 802.11ah

<table>
<thead>
<tr>
<th>Feature</th>
<th>802.11ac</th>
<th>802.11ah</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel bandwidth</td>
<td>20/40/80/160 MHz</td>
<td>1/2/4/8/16 MHz</td>
</tr>
<tr>
<td>FFT size</td>
<td>64/128/256/512</td>
<td>32/64/128/256/512</td>
</tr>
<tr>
<td>Data subcarriers /</td>
<td>52/108/234/468</td>
<td>24/52/108/234/468</td>
</tr>
<tr>
<td>Pilot Sub-carriers</td>
<td>4/6/8/16</td>
<td>2/4/6/8/16</td>
</tr>
<tr>
<td>Pilot Type</td>
<td>Fixed pilot</td>
<td>Fixed pilot or traveling pilot</td>
</tr>
<tr>
<td>Subcarrier spacing</td>
<td>312.5 kHz</td>
<td>31.25 kHz</td>
</tr>
<tr>
<td>OFDM symbol duration</td>
<td>4.0/3.6 us</td>
<td>40/36 us</td>
</tr>
<tr>
<td>Guard interval (short/normal/long)</td>
<td>0.4/0.8/1.6 us</td>
<td>4/8/16 us</td>
</tr>
<tr>
<td>Preamble duration</td>
<td>16 us</td>
<td>320 us (1M BW) / 160 us</td>
</tr>
<tr>
<td>Modulation types</td>
<td>BPSK/QPSK/16QAM/64QAM/256QAM</td>
<td>BPSK/QPSK/16QAM/64QAM/256QAM</td>
</tr>
<tr>
<td>Coding rates</td>
<td>1/2, 2/3, 3/4, 5/6</td>
<td>1/2 rep2, 1/2, 2/3, 3/4, 5/6</td>
</tr>
<tr>
<td>MCS</td>
<td>0-9</td>
<td>MCS0-9, 10</td>
</tr>
<tr>
<td>Transmission Mode</td>
<td>VHT mode, non-HT duplicate mode</td>
<td>Normal mode S1G, 1 MHz duplicate mode, 2 MHz duplicate mode</td>
</tr>
<tr>
<td>Duplicated PPDU</td>
<td>Non-HT PPDU</td>
<td>S1G_DUP_1M, S1G_DUP_2M</td>
</tr>
<tr>
<td>MIMO</td>
<td>Up to 8</td>
<td>Up to 4</td>
</tr>
<tr>
<td>Multi-user</td>
<td>Up to 4</td>
<td>Up to 4, only available in S1G_LONG PPDU</td>
</tr>
<tr>
<td>Beamforming</td>
<td>Support</td>
<td>Support</td>
</tr>
</tbody>
</table>

Source: Draft Amendment Proposed by 802.11 TGah Working Group
# 802.11ah Physical Layer Measurements

## Transmitter Tests

<table>
<thead>
<tr>
<th>Test</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmitter Power</td>
<td></td>
</tr>
<tr>
<td>Spectrum Mask</td>
<td>24.3.17.1</td>
</tr>
<tr>
<td>Transmission spurious</td>
<td></td>
</tr>
<tr>
<td>Center frequency tolerance</td>
<td>24.3.17.3</td>
</tr>
<tr>
<td>Symbol clock frequency tolerance</td>
<td>24.3.17.3</td>
</tr>
<tr>
<td>Center frequency leakage</td>
<td>24.3.17.4.2</td>
</tr>
<tr>
<td>Spectral flatness</td>
<td>24.3.17.2</td>
</tr>
<tr>
<td>Constellation error</td>
<td>24.3.17.4.3</td>
</tr>
<tr>
<td>Modulation accuracy</td>
<td>24.3.17.4.4</td>
</tr>
</tbody>
</table>

## Receiver Tests

<table>
<thead>
<tr>
<th>Test</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Input Sensitivity</td>
<td>24.3.18.1</td>
</tr>
<tr>
<td>Adjacent channel rejection</td>
<td>24.3.18.2</td>
</tr>
<tr>
<td>Non-adjacent channel rejection</td>
<td>24.3.18.3</td>
</tr>
<tr>
<td>Maximum input level</td>
<td>24.3.18.4</td>
</tr>
<tr>
<td>Clear channel assessment</td>
<td>24.3.18.5</td>
</tr>
<tr>
<td>RSSI</td>
<td>24.3.18.6</td>
</tr>
</tbody>
</table>

Reference: IEEE 802.11ah draft amendment proposed by 802.11 TGah Working Group
IoT Key Enabling Technologies
IEEE 802.11p – Now

- A Wi-Fi (IEEE 802.11p: Amendment 6, Wireless Access in Vehicular Environment (WAVE) based technology to support low latency, Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2X) communication
  - Vehicle broadcasts its position and velocity and receives broadcasts of neighboring road users
  - Frequency range: 5.85-5.925 GHz
  - Developed based on 802.11a but targets for reliable connection
- Main uses:
  - Vehicle safety services
  - Commerce transactions via cars
  - Toll collection
  - Traffic management
- USA, Europe, China, Japan, Korean and Singapore are working towards hard/soft mandate or MOU for DSRC installation.
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Bluetooth® Standard Evolution

- **1999**: V1.0
  - Many problems
  - Difficult making products interoperable

- **2003**: V2.0 + EDR
  - Faster connection/discovery
  - Use AFH
  - Up to 721 kbps

- **2004**: V2.1 + EDR
  - Alternate MAC/PHY
  - Unicast connectionless data
  - Enhanced power control
  - HS up to 24 Mbps

- **2007**: V3.0 + HS
  - SSP, EIR
  - Power consumption optimization

- **2009**: V4.0
  - Adoption of Bluetooth LE
  - LE up to 260 kbps
  - Including classic, LE and HS

- **2010**: V4.1
  - Coexist with 4G
  - Smart connectivity
  - Data transfer improvement

- **2013**: V4.2
  - For IoT (Support IPv6/6LoWPAN)
  - High privacy
  - Data throughput increase (10x packet capacity increase)

- **2014**: Future

**Future**

Bluetooth Smart competes directly with ANT+ for low power applications (sensors, etc.)

Two New Trademarks for Certified BT Devices

For dual-mode: LE + Legacy BT

For single-mode: LE only
Bluetooth Low Energy Channel Allocations

- 3 advertising channels (37, 38, 39)
- 37 data channels
- 0.6-1.2 ms for scanning

Classic Bluetooth:
- 32 hop frequencies for same task
- 22.5 ms

< 10 – 20 times less power
Test Challenges for Bluetooth LE Devices
Simple, Standard-compliant, Fast

- Testing for Bluetooth Smart was simplified compared to legacy Bluetooth
- Bluetooth SIG created specific guidelines for BLE qualification
  - BLE defined a reference signal to simplify RF performance testing
- Legacy Bluetooth formats (Basic and EDR) are supported for Dual Mode and Single Mode testing
  - Auto detection capability – quickly Bluetooth format detection
  - Time effective for in-band spurious emission test – FFT vs. swept
  - Easy to use signal generation - pre-defined dirty package with frequency drift for Rx sensitivity test
# Bluetooth Low Energy RF PHY Test Cases

## Transmitter Tests

<table>
<thead>
<tr>
<th>Test Description</th>
<th>Test Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output power at NOC</td>
<td>TRM-LE/CA/01/C</td>
</tr>
<tr>
<td>Output Power at EOC</td>
<td>TRM-LE/CA/02/C</td>
</tr>
<tr>
<td>In-band emissions at NOC</td>
<td>TRM-LE/CA/03/C</td>
</tr>
<tr>
<td>In-band emissions at EOC</td>
<td>TRM-LE/CA/04/C</td>
</tr>
<tr>
<td>Modulation characteristics</td>
<td>TRM-LE/CA/05/C</td>
</tr>
<tr>
<td>Carrier frequency offset and drift at NOC</td>
<td>TRM-LE/CA/06/C</td>
</tr>
<tr>
<td>Carrier frequency offset and drift at EOC</td>
<td>TRM-LE/CA/07/C</td>
</tr>
</tbody>
</table>

## Receiver Tests

<table>
<thead>
<tr>
<th>Test Description</th>
<th>Test Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receiver sensitivity at NOC</td>
<td>RCV-LE/CA/01/C</td>
</tr>
<tr>
<td>Receiver sensitivity at EOC</td>
<td>RCV-LE/CA/02/C</td>
</tr>
<tr>
<td>C/I and receiver selectivity performance</td>
<td>RCV-LE/CA/03/C</td>
</tr>
<tr>
<td>Blocking performance</td>
<td>RCV-LE/CA/04/C</td>
</tr>
<tr>
<td>Intermodulation performance</td>
<td>RCV-LE/CA/05/C</td>
</tr>
<tr>
<td>Maximum input signal level</td>
<td>RCV-LE/CA/06/C</td>
</tr>
<tr>
<td>PER Report Integrity</td>
<td>RCV-LE/CA/07/C</td>
</tr>
</tbody>
</table>

- **NOC**: normal operating conditions
- **EOC**: extreme operating conditions
- **NOC and EOC** tests are the same except the operating conditions (extreme temperature, air humidity, supply voltage)
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IoT Key Enabling Technologies
ZigBee (802.15.4) - Now

- Target is M2M (IoT): low power, low data rate, mesh network
  - Conceived in 1998, standardized in 2003, and revised in 2006
  - Based on 802.15.4 physical and MAC layers
  - ZigBee Alliance was established in 2002 with 400+ members

- Target Use Case
  - Industrial and commercial
  - Personal healthcare
  - Building automation
  - Automotive

- PHY/MAC/Network
  - Used in 784 MHz (China), 868 MHz (EU), 915 MHz (USA), 2.4 GHz ISM bands
  - Conforms to IEEE 802.15.4 PHY & MAC layer definition
  - Multiple traffic types: periodic, intermittent and repetitive low latency data
### ZigBee (IEEE 802.15.4) Physical Layer Specification

<table>
<thead>
<tr>
<th>PHY (MHz)</th>
<th>Frequency band (MHz)</th>
<th>Spreading parameters</th>
<th>Data parameters</th>
<th>Channel Spacing (MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>868*/915*</td>
<td>868 (Europe)</td>
<td>300/400/400</td>
<td>BPSK/ASK/O-QPSK</td>
<td>20/250/100</td>
</tr>
<tr>
<td></td>
<td>915 (North America)</td>
<td>600/1600/1000</td>
<td>BPSK/ASK/O-QPSK</td>
<td>40/250/250</td>
</tr>
<tr>
<td>2450 DSSS</td>
<td>2400-2483.5 (World)</td>
<td>2000</td>
<td>O-QPSK</td>
<td>250</td>
</tr>
</tbody>
</table>

* optional

- Range: 10 – 75 meters (depending on the environment)
- Radio Power Requirements: 1 mW – 100 mW
- Transmit Center Frequency Tolerance: ±40 ppm
- Receiver Sensitivity (PER < 1%): -85 dBm @ 2.4 GHz band; -92 dBm @ 868/915 MHz band
- Modulation and channel access: DSSS and CSMA/CA

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# IEEE 802.15.4 O-QPSK PHY RF Requirements

## Transmitter Test

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating frequency range</td>
<td>10.3.1</td>
</tr>
<tr>
<td>Transmitter power spectral density (PSD Mask (SEM))</td>
<td>10.3.2</td>
</tr>
<tr>
<td>Symbol rate</td>
<td>10.3.3</td>
</tr>
<tr>
<td>Error vector magnitude (EVM)</td>
<td>10.3.8</td>
</tr>
<tr>
<td>Transmitter center frequency tolerance</td>
<td>10.3.9</td>
</tr>
<tr>
<td>TX-to-Rx turnaround time</td>
<td>10.3.6</td>
</tr>
<tr>
<td>RX-to-Tx turnaround time</td>
<td>10.3.7</td>
</tr>
</tbody>
</table>

## Receiver Test

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receiver sensitivity</td>
<td>10.3.4</td>
</tr>
<tr>
<td>Receiver interference rejection</td>
<td>10.3.5</td>
</tr>
<tr>
<td>Receiver maximum input level</td>
<td>10.3.11</td>
</tr>
<tr>
<td>Receiver ED</td>
<td>10.3.12</td>
</tr>
<tr>
<td>Link quality indicator</td>
<td>10.3.13</td>
</tr>
<tr>
<td>Clear channel assessment</td>
<td>10.3.14</td>
</tr>
</tbody>
</table>

Reference: IEEE Std 802.15.4 Low-Rate Wireless Personal Area Networks (LR-WPANS) Ver. 2011
IoT Key Enabling Technologies
Wi-SUN (802.15.4) - Now

– Wi-SUN is developed based on IEEE 802.15.4g standard
  • Target use case: wireless smart utility networks
  • Conformance, interoperability, and certification testing has been defined
  • Wi-SUN Alliance has > 40 members
  • Conformance tests and profiles are developed for the popular MR-FSK PHY
    • MR-OFDM PHY is available but not as popular

– PHY/MAC Layer
  • 3 physical layer (PHY) standards supported:
    - MR-FSK: 2FSK and 4FSK modulation used
    - MR-OFDM: 4 options with different FFT size and bandwidths
    - MR-O-QPSK: DSSS and multiplexed DSSS used
  • Frequency bands depend on regulatory requirements, may include bands around:
    - 169, 450-510, 780, 863-870, 896-960, 1427-1518, and 2400-2483 MHz
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NFC - Now

NFC uses magnetic induction between two loop antennas located within each other's near field, effectively forming an air-core transformer.

- Based on RFID technology at 13.56 MHz
- Operating distance typically up to 10 cm
- Data exchange rate typically used today up to 848 kbps
- Compatible with today's contactless RFID technologies
- NFC is complementary to Bluetooth and Wi-Fi technologies
- Three modes of operation:
  - Peer Mode (P2P)
  - Reader/Writer (R/W)
  - Card Emulation (CE)
**NFC Technologies**

NFC-A, B or F

NFC device may support one or more technologies (NFC-A, B or F)

<table>
<thead>
<tr>
<th>Technology</th>
<th>Poller/Listener</th>
<th>Data Rate (kbit/s)</th>
<th>Coding</th>
<th>Modulation</th>
<th>Carrier frequency (MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NFC-A Based on ISO 18092</td>
<td>Poller</td>
<td>106</td>
<td>Modified Miller</td>
<td>ASK 100%</td>
<td>13.56</td>
</tr>
<tr>
<td></td>
<td>Listener</td>
<td>106</td>
<td>Manchester</td>
<td>Load Modulation (ASK)</td>
<td>13.56 (+/- 848 kHz)</td>
</tr>
<tr>
<td>NFC-B Based on ISO 14443B</td>
<td>Poller</td>
<td>106</td>
<td>NRZ-L</td>
<td>ASK 10%</td>
<td>13.56</td>
</tr>
<tr>
<td></td>
<td>Listener</td>
<td>106</td>
<td>NRZ-L</td>
<td>Load modulation (BPSK)</td>
<td>13.56 (+/- 848 kHz)</td>
</tr>
<tr>
<td>NFC-F Based on ISO 18092</td>
<td>Poller</td>
<td>212/424</td>
<td>Manchester</td>
<td>ASK 10%</td>
<td>13.56</td>
</tr>
<tr>
<td></td>
<td>Listener</td>
<td>212/424</td>
<td>Manchester</td>
<td>Load modulation (ASK)</td>
<td>13.56 (+/- 848 kHz)</td>
</tr>
</tbody>
</table>
NFC Testing

Main Certification Programs

NFC Forum

- Covers proximity Technologies A, B and F.
- Planning to add vicinity technology soon (15693)
- Device supports R/W, P2P and CE (optional)
- Test require DTA
- Accredited certification labs

EMV contactless (EMVCo)

- Specs and certification program for payment devices
- Contact testing (ISO/IEC 7816)
- Contactless testing (ISO/IEC 14443 A and B)
- L2 according to each payment scheme
Agenda

- IoT/M2M Introduction and Market Situation
  - What is IoT?
  - Wireless technologies in IoT

- IoT/M2M Key Enabling Technologies
  - WLAN 802.11ah and 802.11p
  - Bluetooth Low Energy
  - ZigBee (802.15.4) and Wi-SUN (802.15.4g)
  - NFC

- IoT/M2M Test Solution
  - Bench-top solution for R&D
  - One-box test or low cost solution for Manufacturing
Bench-top Test Solution for R&D and DVT

Signal Generation and Analysis

- **IoT/M2M Signal Generation Solution**
  - Signal Studio **software** with format support for:
    - WLAN 802.11a/b/g/j/p/n/ac/ah
    - Bluetooth (BR/EDR/LE)
    - ZigBee (802.15.4) and Wi-SUN (802.15.4g)
  - **Compatible hardware**: X-Series signal generators (MXG/EXG), PSG, AWG, PXIe VSG, EXM one box tester

- **IoT/M2M Signal Analysis Solution**
  - One-button embedded measurement applications supporting:
    - WLAN 802.11a/b/g/j/p/n/ac/ah
    - Bluetooth (BR/EDR/LE)
    - ZigBee (802.15.4) and Wi-SUN (802.15.4g)
  - **Compatible hardware**: X-Series signal analyzers (PXA, MXA, EXA), PXIe VSA, EXM one box tester
E6640A EXM Wireless Test Set for DVT and Mfg

Broadest Multi-Format Coverage

**Cellular**
- LTE/LTE-A FDD/TDD
- HSPA+, W-CDMA
- 1xEV-DO, cdma2000
- GSM/EDGE/EDGE Evo
- TD-SCDMA/TD-HSPA
- DECT
- PHS

**Wireless Connectivity**
- WLAN 802.11a/b/g/n/j/p/ac/ah
- Bluetooth 1.0 to 4.2
- ZigBee
- Multi-Satellite GNSS
- Plus more

**MIMO (2x2, 3x3, 4x4)**
Low Cost Solution for High-Volume Manufacturing
For ZigBee and Wi-SUN

Receiver RF Test

33500 series function gen

33503A BenchLink Waveform Builder Pro

N9310A RF signal generator

Transmitter RF Test

N9320B/22C Basic Spectrum Analyzer (BSA)

For demodulation of FSK signals

N9000A CXA X-Series signal analyzer

Supports demodulation of wireless formats using ≤ 25 MHz transmission bandwidth
Keysight T3111S NFC/EMV Conformance Tester

**EMV**
- EMV L1 RF* and Digital Protocol
  - PICC/Mobile **qualified!**
  - PCD

**NFC Forum**
- Digital Protocol
- Analog RF
- LLCP
- SNEP

**ISO/IEC**
- 14443 A/B
- 18092
- 15693
- 18000-3

---

**T1142A Automated Positioning Robot**
- Enables device characterization at user-defined positions
- Fulfils NFC and EMV Contactless test specifications requirements
- Free guard area with no metallic parts
- 0.25mm positioning accuracy
- API to incorporate third party Robots available.

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* EMV Level 1 RF parts offered in cooperation with FIME

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IoT/M2M Webcast  Page 35
Keysight Solutions Covering the whole Lifecycle

RF Module Development
- RF Proto
- RF Chip/module

BB Chipset Development
- L1/PHY
- FPGA and ASIC

Protocol Development
- L2/L3

RF and BB Design Integration
- L1/PHY

System Design Validation
- System Level RF Testing

Conformance
- Pre-Conformance

Manufacturing
- Manufacturing

Network Deployment
- Network Deployment

Signalling RF, Protocol and Function Test
- N4010A Wireless Connectivity Test Set
- Power Measurement

NFC/EMV Conformance/R&D/Mfg Test

RF Handheld Analyzer
- Manufacturing Test

Cellular / Bluetooth Conformance Test System

3D EM Simulation
- SystemVue (BB)
- ADS/GG (RF/A)

Battery Drain Characterization
- PXI Modular Solutions
- Scopes and Logic Analyzers
- 89600 VSA/WLA

Battery Drain Characterization
Resources

- For additional information regarding IoT solutions, refer to the Keysight Application websites
  - ZigBee: http://www.Keysight.com/find/Zigbee

Thank you!
Backup
# Keysight IoT Test Solution Summary

## Wireless Technologies

<table>
<thead>
<tr>
<th>Standards</th>
<th>Transmitter Test (R&amp;D &amp; DVT)</th>
<th>Receiver Test (R&amp;D &amp; DVT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>802.11ah &amp; 802.11p</td>
<td>SW: N7617B, HW: MXG, EXG, PXI VSG (MIMO)</td>
<td>SW: N9077A, 89601B, HW: X-Series SA, PXI VSA (MIMO)</td>
</tr>
<tr>
<td>ZigBee (802.15.4)</td>
<td>SW: N7610B, HW: MXG, EXG, PXI VSG</td>
<td>SW: N9064A, 89601B, HW: X-Series SA, PXI VSA</td>
</tr>
<tr>
<td>Wi-SUN (802.15.4g)</td>
<td>SW: N7610B, HW: MXG, EXG, PXI VSG</td>
<td>SW: N9064A, 89601B (FSK&amp;OQPSK), 89600B (Custom OFDM), HW: X-Series SA, PXI VSA</td>
</tr>
<tr>
<td>Z-Wave (ITU G.9959)</td>
<td>Waveform file</td>
<td>SW: N9064A or 89601B, HW: X-Series SA</td>
</tr>
<tr>
<td>NFC</td>
<td>HW: T3111S-H01, T1142A, T3111S-CH1, T3111S-CH2, SW: T3111S-V0x T3111S-C0x, T3111S-Shx, T3111S-D0x</td>
<td></td>
</tr>
</tbody>
</table>
## Keysight IoT Test Solution Summary

### Wireless Technologies

<table>
<thead>
<tr>
<th>Standards</th>
<th>One Box Tester (DVT &amp; Manufacturing)</th>
<th>Low Cost Solution (High Volume Manufacturing)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZigBee (802.15.4)</td>
<td>SW: N7610B, V9064A, 89601B HW: E6640A</td>
<td>SW: Waveform file, W9064A HW: 335xx/336xx, N9310A, N9320A, N9000A</td>
</tr>
<tr>
<td>Wi-SUN (802.15.4g)</td>
<td>SW: N7610B, V9064A, 89601B HW: E6640A</td>
<td>SW: Waveform file, W9064A HW: 335xx/336xx, N9310A, N9320A, N9000A</td>
</tr>
</tbody>
</table>
Keysight WLAN (802.11a/b/g/j/p/n/ac/ah) Solutions

Signal Generator
For Rx Part Tests
X-Series SG (MXG or EXG) + N7617B WLAN Signal Studio

Signal Analyzer
For Tx Part Tests
X-Series SA (PXA/MXA/EXA/CXA) + N9077A & W9077A WLAN Measurement Application

One-Box-Tester
For Tx/Rx Tests in Mfg with non-signaling tests
E6640A EXM (non-signaling) + V9077A WLAN Measurements Application

PXI VSA/VSG
For MIMO and Beamforming test
PXI VSA/VSG (M9381A/M9391A) + M9077A WLAN Measurements Application
<table>
<thead>
<tr>
<th>Keysight Bluetooth Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Signal Generator</strong></td>
</tr>
<tr>
<td><em>For Rx Part Tests</em></td>
</tr>
<tr>
<td>X-Series SG (MXG or EXG)</td>
</tr>
<tr>
<td><strong>Signal Analyzer</strong></td>
</tr>
<tr>
<td><em>For Tx Part Tests</em></td>
</tr>
<tr>
<td><strong>One-Box-Tester</strong></td>
</tr>
<tr>
<td><em>For Tx/Rx Tests in mfg with signaling or non-signaling tests</em></td>
</tr>
<tr>
<td>E6640A EXM (non-signaling)</td>
</tr>
</tbody>
</table>
**Keysight Short Range Communication Solutions (ZigBee/Wi-SUN)**

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Signal Generator</strong></td>
<td>For Rx Part Tests</td>
<td>N7610B WLAN Signal Studio</td>
</tr>
<tr>
<td></td>
<td>X-Series SG (MXG or EXG)</td>
<td></td>
</tr>
<tr>
<td><strong>Signal Analyzer</strong></td>
<td>For Tx Part Tests</td>
<td>N9064A VX A Measurement Application</td>
</tr>
<tr>
<td></td>
<td>X-Series SA (PXA/MXA/EXA/CXA)</td>
<td>89601B w/ AYA</td>
</tr>
<tr>
<td><strong>One-Box-Tester</strong></td>
<td>For Tx/Rx Tests in Mfg with non-signaling tests</td>
<td>V9064A VX A Measurements Application</td>
</tr>
<tr>
<td></td>
<td>E6640A EXM (non-signaling)</td>
<td></td>
</tr>
<tr>
<td><strong>Low Cost Solution</strong></td>
<td>For high-volume Mfg Tx/Rx Tests</td>
<td>W9064A VX A Measurements Application</td>
</tr>
<tr>
<td></td>
<td>AWG (335xx/336xx)</td>
<td>89601B VSA w/AYA</td>
</tr>
<tr>
<td></td>
<td>Basic SG (N9010A)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>N9000A (CXA)</td>
<td>IoT/M2M Webcast</td>
</tr>
</tbody>
</table>
Keysight T3111S Test System Foundation

Integrated RF and protocol test system with card and terminal emulation

Test Manager for automatic test suite execution

Intuitive Virtual Front Panel for R&D and debug

Keysight T1141A Test Set

Keysight T1142A Robot

Automatic positioning robot for accurate and repeatable antenna location
NFC R&D Solution

Test App runs in Scope, or remote control by external PC