5 things you want to know about Bluetooth® 5
How Texas Instruments SimpleLink™ CC2640R2F wireless MCU is enabling Bluetooth® 5 solutions development for industrial applications

element14 – Texas Instruments Webinar
Bluetooth low energy wireless MCUs
www.ti.com/ble
June 28th 2017
Agenda

• What is Bluetooth 5 and what is new?

• Bluetooth 5 benefits use cases examples

• Technical details

• TI solution for Bluetooth 5

• Getting Started with TI
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## Wireless Connectivity is *EVERYWHERE*

<table>
<thead>
<tr>
<th>Automotive</th>
<th>Motor drives</th>
<th>Building automation</th>
<th>Smart grid</th>
<th>Factory automation</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Automotive" /></td>
<td><img src="image2.png" alt="Motor drives" /></td>
<td><img src="image3.png" alt="Building automation" /></td>
<td><img src="image4.png" alt="Smart grid" /></td>
<td><img src="image5.png" alt="Factory automation" /></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Wearables</th>
<th>Audio</th>
<th>Home Electronics</th>
<th>Smart Peripherals</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image6.png" alt="Wearables" /></td>
<td><img src="image7.png" alt="Audio" /></td>
<td><img src="image8.png" alt="Home Electronics" /></td>
<td><img src="image9.png" alt="Smart Peripherals" /></td>
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</tbody>
</table>
### Bluetooth® low energy vs other Bluetooth® spec

<table>
<thead>
<tr>
<th>Bluetooth® Classic</th>
<th>Bluetooth® Dual Mode</th>
<th>Bluetooth® Low Energy (BLE)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Keyboard and headphones" /></td>
<td><img src="image2.png" alt="Smartphone, tablet, and laptop" /></td>
<td><img src="image3.png" alt="Miscellaneous gadgets" /></td>
</tr>
<tr>
<td><strong>Power Required:</strong></td>
<td><strong>Power Required:</strong></td>
<td><strong>Power Required:</strong></td>
</tr>
<tr>
<td>AAA</td>
<td>AAA</td>
<td>Coin cell</td>
</tr>
<tr>
<td>• Optimized for audio applications</td>
<td>• Bluetooth® Dual Mode = Bluetooth® Classic + Bluetooth® Low Energy</td>
<td>• Custom profile, allows any application</td>
</tr>
<tr>
<td>• Higher throughput up to 3Mbps</td>
<td></td>
<td>• Lower power consumption than Bluetooth® (down to 1/10th), multiyear on Coin Cell Battery</td>
</tr>
<tr>
<td>• In all existing phones, tablets, laptops</td>
<td></td>
<td>• Throughput up to 2Mbps</td>
</tr>
</tbody>
</table>
Bluetooth low energy industry trends

“Fastest growing wireless technology”
– ABI Research

**Challenges**
- Speed
- Range
- Low Power
- Coexistence

**Personal Area Networks**
2010-2016

**Local Area Networks/ House coverage**
2017 onwards

Bluetooth 5 is the future
Bluetooth 5 is the future

Source www.bluetooth.com/bluetooth5
## BLE Specifications and Features

<table>
<thead>
<tr>
<th>Spec</th>
<th>Bluetooth® 4.0</th>
<th>Bluetooth® 4.1</th>
<th>Bluetooth® 4.2</th>
<th>Bluetooth® 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed (max)</td>
<td>1 Mbps</td>
<td>1 Mbps</td>
<td>1 Mbps</td>
<td>2 Mbps</td>
</tr>
<tr>
<td>Packet Capacity</td>
<td>27 bytes</td>
<td>27 bytes</td>
<td>251 bytes</td>
<td>251 bytes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(2.5x faster)</td>
<td>(4x faster @ 2 Mbps)</td>
</tr>
<tr>
<td>Multi-role</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>LE Secure Connections</td>
<td>-</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>LE Privacy 1.2</td>
<td>-</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Coded PHY Enable</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>Longer Range (125kbps/500kbps)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td>Advertisement Extension</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>✓</td>
</tr>
</tbody>
</table>
Agenda

• What is Bluetooth 5 and what is new?

• **Bluetooth 5 benefits use cases examples**

• Technical details

• TI solution for Bluetooth 5

• Getting Started with TI
Long Range use case: door lock

• Reliable house coverage
  – Reach your lock from anywhere in the house with your phone
  – Remove repeaters
  – Door lock can reach access point and integrates Smart Home system

• Less retransmission, less power

Benefits for additional applications

- Reliable building automation coverage
- Improved range in noisy 2.4GHz space
- Wider tracking zone, improves coverage

Appliance
HVAC
Industrial sensor network
Advertising extension use case: Beacon

- Advertising Extension
  - Transmit more information over beacon (31 bytes to 255 bytes).
  - More personalized experience (locationing beacon gives more precise information)
  - Connection-less beacons: beacon always sending information w/o hand-shake leading to quicker, richer notification

Benefits for additional applications

- Advanced beacon applications for asset tracking & indoor navigation
- Connection-less applications
Faster data transfer use case: industrial

- High speed mode
  - Lower power thanks to shorter air time
  - Faster Data Logging and Diagnostic
  - Faster firmware upgrade

More applications, more Innovation

More data for Biometric authorization systems

Low latency application-level cryptographic key/certificate exchanges

Faster user experience
Agenda

- What is Bluetooth 5 and what is new?
- Bluetooth 5 benefits use cases examples
- Technical details
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- Getting Started with TI
Bluetooth 5: Longer range

Increased Receiver Performance with LE-Coded PHY

• Bluetooth 4.x LE uses 1Mbps un-coded PHY
  – 1:1 ratio between transmitted data bits and over-the-air modulated symbols
  – Single bit error in transmission requires re-transmission of entire PDU (CRC error)
  – Good for low-noise or shorter range communication

• Bluetooth 5 introduces Coded PHY rates of 500kbps and 125kbps
  – Uses Forward Error Correction (FEC) to code the payload data bits 1:2
  – This can be used as is with a data rate of 500 kbps (N = 2 coding)
  – The bits can be expanded 1:4 (a ‘0’ expands to ‘0011’ and a ‘1’ is expanded to ‘1100’)
  – Gives a data rate of 125 kbps (N = 8 coding)
  – More over-the-air modulated symbols are used for each actual data bit. This makes it easier for the receiver to distinguish the signal over noise and Sensitivity improves
  – RX current consumption is unchanged compared to un-coded PHY

More technical details available in our blogs [here](#)
Bluetooth 5: Higher speed

New 2Mbps LE PHY mode

- 2x throughput compared to BT4.x LE
  - 2 MSymbol/s rate un-coded
  - Backwards compatible with BT4.x 1Mbps devices since LE Controllers negotiate link speed

<table>
<thead>
<tr>
<th>BT4.0/4.1</th>
<th>BT4.2</th>
<th>BT5.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>1Mbps PHY</td>
<td>1Mbps PHY</td>
<td>2Mbps PHY</td>
</tr>
<tr>
<td>27 byte PDU</td>
<td>27-255 byte PDU with Data Length Extension</td>
<td>27-255 byte PDU with Data Length Extension</td>
</tr>
<tr>
<td>305 kbps</td>
<td>780 kbps</td>
<td>1.4 Mbps</td>
</tr>
</tbody>
</table>

Maximum Throughput (LE) by specification
Bluetooth 5: Advertisement extension

- Legacy Bluetooth LE Advertisement
  - Primary channels: 37, 38, 39
  - PDU size 6-37 bytes at 100ms non-connectable or 20ms connectable max rate
  - PHY: 1Mbps only

- New Advertising channel extension PDU: ADV_EXT_IND
  - Allows up to 248 byte ADV payload by offloading payload to Data channels
  - Supports any PHY
  - Reduces traffic on ADV channels
  - Mandatory for Coded PHYs

\[ t_{min} = 300\text{us} \]
\[ t_{max} = 2.4\text{s} \]
Bluetooth 5: Random Frequency Hopping for a more robust connection

• BT 4.x LE channel hopping scheme:
  – nextChannel = (previousChannel + hopIncrement) mod 37
  – hopIncrement = <5, 16>
    • 12 different hopping patterns

• BT 5.x LE channel hopping scheme:
  – Pseudo random sequence
  – Adjacent connection event will have a guaranteed minimum frequency separation
TI Radio: a unique future proof differentiation

• The BT5 long range mode specification is based on a proposal from TI

• **Flexible radio** also ensures support for future spec enhancements via software update

• Support of up to **5Mbps** for future expandability
Achieve 1.5km with Bluetooth 5 with TI’s long range mode

SimpleLink™ Academy

*Long Range with CC2640R2F Bluetooth® 5 Preview*

1.5 km Line of Sight Demo
Coded PHYs and Link Budget Explained

Video link

Read more: technical blog
Bluetooth 5: Link Budget Improvement

- RF Link budget is the ratio between the transmit RF power and the receiver sensitivity level

- Link budget can be increased by:
  - Increasing output power
    - Which will increase current consumption
      - Current consumption typically increases significantly above 0 dBm for available BLE wireless MCUs
    - Data rate is unchanged
  - Improving receiver sensitivity through coding techniques
    - Current consumption is unchanged
    - Data rate is reduced
    - Leveraged in BT5 Coded PHYs (500 kbps and 125 kbps)
Sensitivity and RF link budget

- **Link budget** [dB] = **TX Power** [dBm] - **Sensitivity level** [dBm]

- **Example for CC2640R2F @ 125 kbps**: 5 dBm - (-103 dBm) = 108 dB
  - 6 dB improvement in link budget compared to 1 Mbps – same low current

---

TX power: +5dBm

- Link budget = 102 dB
- RX sensitivity @ 1Mbps: -97dBm

- Link budget = 108 dB
- RX sensitivity @125 kbps: -103dBm
Transmit power and current consumption

• TX PA current typically starts dominating the total current consumption for output power levels above 0 dBm

• Most BLE applications run at 0 dBm output power
  – CC2640R2F current consumption at 0 dBm is only 6 mA

• CC2640R2F can output up to 5 dBm while keeping the current consumption below 10 mA
  – Allows the application to run off common coin cell batteries

• With **CC2640R2F**, using the new Bluetooth 5 coded PHY, we can achieve a BLE range of **more than 1.5 kilometers** while still maintaining a peak current consumption below 10 milliamps.
*Texas Instruments Bluetooth 5 Long Range Demo

< Next Item
  Toggle RSSI Readings >
  Disconnect
PHY Update Complete

Peer Device: 0xB0912269EC41
Current PHY: Coded:S8
RSSI -dBm: 75
Object Temperature: 19 (C)
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TI Bluetooth 5
BLE5-Stack 1.0 solution
SimpleLink™ CC2640R2F BLE WMCU
+ Fully certified SW

- First Fully qualified Bluetooth 5 release in the market
- High Speed Mode
- Long Range Demo
- Industry’s smallest Flash based Bluetooth 5 WMCU
- Lowest Power for Best RF performance
- Future Proof Platform
CC2640R2F SimpleLink Bluetooth Low Energy Wireless MCU

Full production today – future proof BT 5 solution for tomorrow

5 need to know facts about the new SimpleLink™ Bluetooth low energy CC2640R2F wireless MCU

**Application MCU**
- Application
- Profiles / services
- TI RTOS
- Peripheral drivers and libraries
- Royalty free protocol stacks

**Peripherals / modules**
- DC/DC converter
- Temp/battery monitor
- AES
- GPIO
- Timers
- UART / SPI
- I2C / I2S
- DMA

**Radio**
- Flexible, SW defined radio
- Multi-protocoll support
- LinkLayer in ROM

**Sensor controller engine**
- ADC and comparators
- Digital sensor readings
- Capacitive sensing

**Memory**
- 275 KB Non Volatile memory
- Up to 28 KB SRAM

QFN packages options and world smallest flash based wireless MCU (WCSP 2.7x2.7mm)

Automotive qualification (CC2640R2F-Q1)

Platform roadmap

Cloud Based Tools

BT 5.0 Modules
End-to-end development resources

Wired & wireless ARM®-based MCUs
Common software
Development Kits
TI Resource Explorer
Code Composer Studio™ IDE
SimpleLink Academy
Part of the SimpleLink™ MCU platform

Microcontroller  |  Wireless Microcontrollers  |  Wireless Network Processor
MSP432™  |  Bluetooth™ low energy CC2640R2F  |  Sub-1GHz CC1310
Texas Instruments  |  Dual-band CC1350  |  Wi-Fi® CC3220
Texas Instruments  |  100% code reuse  |  Wi-Fi® CC3120
Texas Instruments

SDK

Common software
SimpleLink™ Bluetooth® Low Energy
CC2640R2F / CC2640R2F-Q1: Designed for low-power operation

- Multi-year on a coin cell
- Faster processing
- Optimized radio
- Ultra low sleep current
- Less than 0.15 µA in shutdown
- Unique integrated Sensor Controller

### Ultra-low power

<table>
<thead>
<tr>
<th>When</th>
<th>Parameter @ 3V</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>While processing</td>
<td>µA/MHz on ARM® Cortex®-M3</td>
<td>61 µA/MHz</td>
</tr>
<tr>
<td></td>
<td>Coremark/mA</td>
<td>48.5</td>
</tr>
<tr>
<td></td>
<td>Coremark @ 48MHz CPU</td>
<td>142</td>
</tr>
<tr>
<td>While communicating</td>
<td>Peak current RX</td>
<td>5.9 mA</td>
</tr>
<tr>
<td></td>
<td>Peak current TX</td>
<td>6.1 mA</td>
</tr>
<tr>
<td>While sleeping</td>
<td>µA/MHz on Sensor Controller</td>
<td>8.2 µA/MHz</td>
</tr>
<tr>
<td></td>
<td>Sleep mode with RTC and full memory retention</td>
<td>1 µA</td>
</tr>
</tbody>
</table>

**Best-in-class ULPBench score of 143**
SimpleLink™ Bluetooth® Low Energy
CC2640R2F / CC2640R2F-Q1 Differentiation

1. Best RF performance for lowest power
2. Industry’s smallest flash based WMCU package
3. First fully qualified Bluetooth 5 + supports BLE 4.2 (Full featured including Multi Role), BLE 4.1/4.0
4. Easy BLE with Simple Network Processor
5. Full beacon offering: iBeacon / Eddystone
6. Voice over BLE
7. HomeKit certified
8. Industrial and automotive version available
9. Pin to pin/ software compatible higher memory density roadmap
10. SimpleLink MCU easy to use Tools Ecosystem

1.5km range Line Of Sight demonstrated with Bluetooth 5 Coded PHY

Long Range with CC2640R2F
TI offers two options to add BLE to your application

- **Simple Network processor**: add BLE to existing Host MCU (industrial, flexible architecture)

- **Standalone wireless MCU**: small size, low cost, IoT end node single chip BLE SoC integrating BLE + Host MCU
BLE: Industrial Emerging Applications

Building Automation
- Door locks, Beacons
- Smoke Detectors, Door bells, Lights

Health / Medical
- Glucose Monitors,
- Patient Monitors,
- Drug delivery, Hearing aids

Appliances
- Coffee-Maker,
- Vacuum,
- HVAC

Asset Tracking
- Anti-lost tags,
- Asset tracking
- Personel locator

Electronic Point of Sale
- EPOS Card Readers
- EPOS Printers
- Handheld transaction terminals

Industrial
- Power Tools,
- E-meters,
- Sensors
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Getting started with TI on Bluetooth 5 is easy

- Order a CC2640R2F LaunchPad today: LAUNCHXL-CC2640R2

- Download BLE 5 stack 1.0: *industry’s first Fully qualified Bluetooth 5 protocol stack* for single-mode Bluetooth low energy (BLE) supporting Bluetooth 5 High Speed Mode (www.ti.com/ble)

<table>
<thead>
<tr>
<th>Q3 ID</th>
<th>Q3L ID</th>
<th>Declaration ID</th>
<th>Design Name</th>
<th>Product (s)</th>
<th>Company</th>
<th>Product Type(s)</th>
<th>Spec Name</th>
<th>Date</th>
<th>More Info</th>
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<tr>
<td>95129</td>
<td>Yes</td>
<td>D134431</td>
<td>BLE Stack Core 5.0 Stack for CC2640R2F Devices</td>
<td>SimpleLink™, Qualified low energy CC2640R2F wireless ICO LaunchPad™ development kit, LAUNCHXL-C</td>
<td>Texas Instruments Incorporated</td>
<td>Component (Tabled)</td>
<td>5.0</td>
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<td>Qualcomm® BlueCore™ CSRA6100 BGA controller Subsystem</td>
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<td>Qualcomm® BlueCore™ CSRA6100 Dual Mode HCI Stack</td>
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</table>
High Speed Mode

First Fully qualified Bluetooth 5 release in the market

Long Range Demo

Future Proof Platform

TI Confidential – NDA Restrictions

SimpleLink™ CC2640R2F BLE WMCU

Lowest Power for Best RF performance

Industry’s smallest Flash based Bluetooth 5 WMCU

TI Bluetooth 5 BLE5-Stack 1.0 solution

Start Innovate with TI on Bluetooth 5 today and move to production
Welcome to TI's Cloud-based software development tools!

Access online tools to develop applications and evaluate TI devices. If you don't already have a TI development board, order a LaunchPad or SensorTag today.

https://dev.ti.com/

*Save time*, develop directly in the *Cloud*
TI Low Power Wireless Connectivity Solutions
A strong experience - a long term partner

- Over 1 Billion wireless ICs shipped
- Over 15 years experience in wireless
- Over 5000 customers
TI Low Power Wireless Connectivity Solutions

Worldwide support – 24/7
Thank you for your attention

Start your Bluetooth 5 project today @ www.ti.com/ble