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TI POWER

TI *Live!* BATTERY MANAGEMENT SYSTEMS SEMINAR

EVAN WAKEFIELD

THE NEXT GENERATION WIRELESS BMS USING THE CC2662R-Q1

Agenda

Introduction

WBMS value proposition

WBMS protocol concept overview

Q & A

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Current challenges with BMS in EVs

Pounds of wire are a drag on distance, reliability, price and safety

- Every battery cell must be connected by cable to a monitor, which regulates energy performance
- Warranty repairs due to cable failures are costly, and replacing the battery cell is expensive
- The wiring harness and connectors are a common source of cable failures
- The heavy-duty copper wire required to make the cabling more reliable, produces a bulky labyrinth of battery-management cabling
- Manufacturing complexities for pack assembly

Safety is a critical consideration overall.
Meeting the necessary safety requirements for BMS are rigorous.

TI's WBMS value proposition

Our top priorities for delivering WBMS solutions

Safety & reliability

Performance

Cost

Leading wireless innovation for 20 years

Scalable solutions for all applications

Sub-1GHz

- Best range, up to 20km
- 15 years battery life
- Star or mesh network
- Grid, BA, and more

First TRX in market
First integrated IC in market

Bluetooth®

- Best in class Bluetooth LE
- Lowest power
- Star or Bluetooth mesh
- Locationing

First BLE chip in the market
First XTAL free chip

zigbee

- Robust low power mesh for smart home and buildings
- Zigbee 3.0 support
- Zigbee over SubGHz

ZB board from the beginning
Driving ZB over Sub1GHz

Wi Fi CERTIFIED

- Best IoT Wi-Fi solution
- Most robust in the market
- Best in class security

First WiFi IoT chip in the market
First IC vendor with modules

TI WBMS

- Proprietary protocol for wireless battery management systems.
- ASIL-D Capable at the System Level.

Functional Safety

Wi SUN

- Long range mesh for large networks
- Frequency hopping interference tolerance

TI owned SW stack

THREAD

- IPv6 base mesh protocol for home and building automation
- Flexible network

Early solutions

Multi-protocol

- Best in class multi-band solutions (DMM)

SW defined radio enable the space

matter

- Connected Home over IP
- Smart Home seamless connection with different ecosystems
- Builds on top of IP protocols

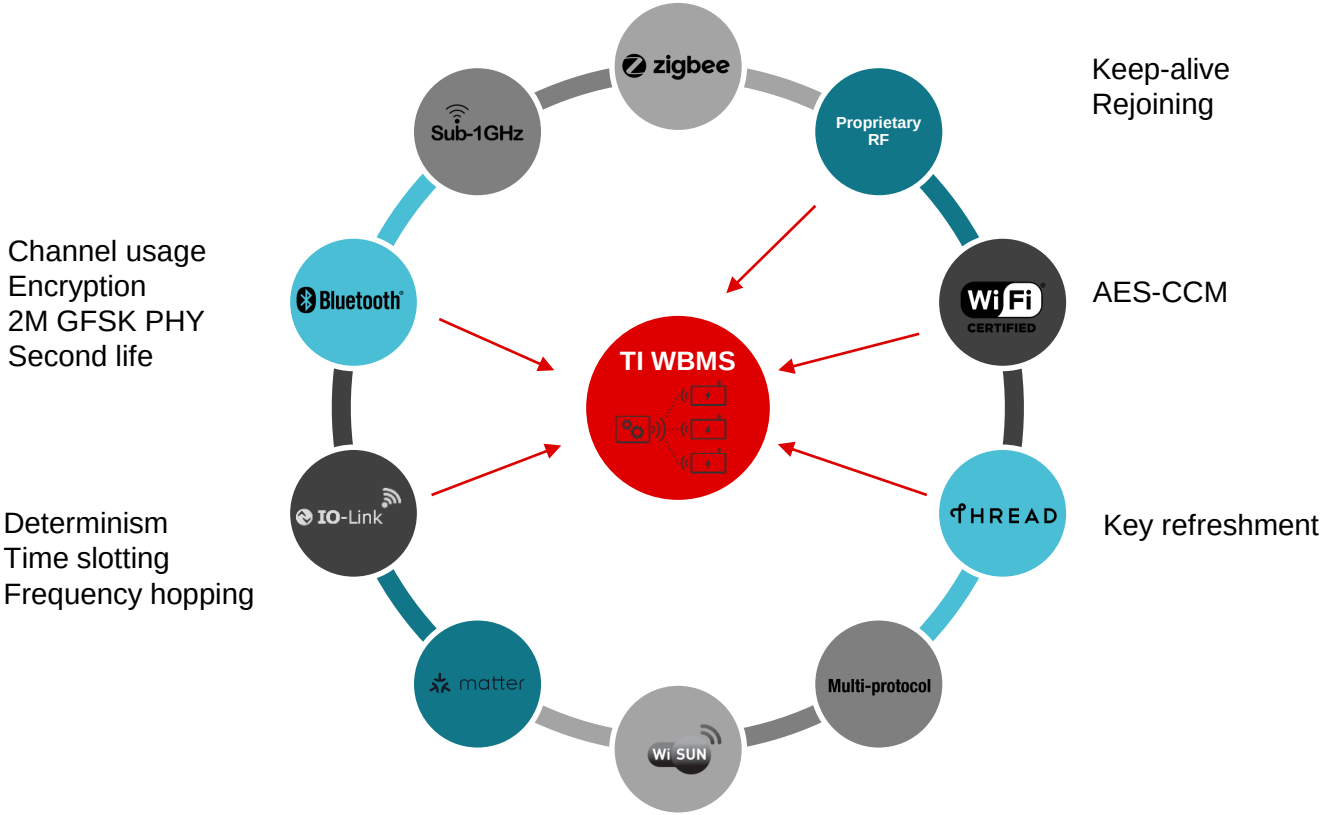
Early solutions

Proprietary and other

- Use our TI MAC15.4 stack or build your own protocol from scratch
- MIOTY, 6LoPAN, wMBUS and more
- Automotive solutions

Leading wireless innovation for 20 years

Building a robust solution design to solve BMS requirements



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CC2662R-Q1 device overview

Identity

- Arm® Cortex®-M4 wireless MCU targeting wireless BMS and cable replacement applications
- AEC-Q100 compliant device optimized for low-power wireless automotive applications

Key Features

- TI wireless BMS protocol
- 2.4GHz
- Functional Safety Quality-Managed device
- AEC-Q100-Qualified at the Grade 2 temperature range (-40ºC to +105ºC)
- Extended temperature for automotive applications (TA = 105ºC)
- Low Power:
  - Wide voltage range: 1.8 V to 3.63 V
  - Active-mode RX: 6.9 mA
  - Active-mode TX: 0 dBm: 7.3 mA
  - Active mode: 71 uA/MHz
  - Standby: 0.94 µA (CPU retention, 80 KB RAM)

Key Device Specification

- Arm® Cortex®-M4
- 352 kB of flash, 88kB total SRAM, 256 kB of system ROM
- 2 UART, 2 SPI, I2C and I2S
- Sensor controller
- Enhanced security (hardware acceleration, AES-128/256, SHA-2, TRNG, ECC, RSA-2048)

Packages

- QFN48 WF 7 mm x 7 mm

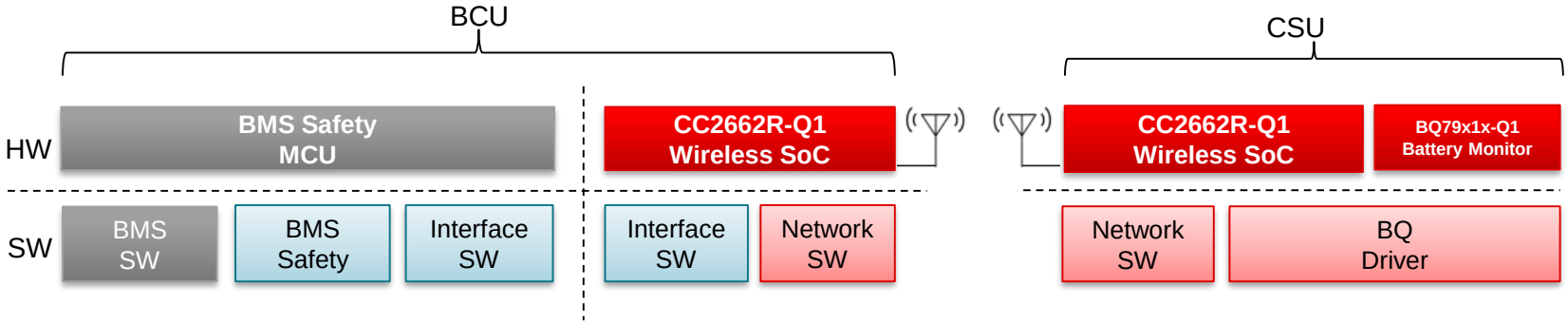
Key applications

- Automotive – wireless battery management system
- Cable replacement

Availability

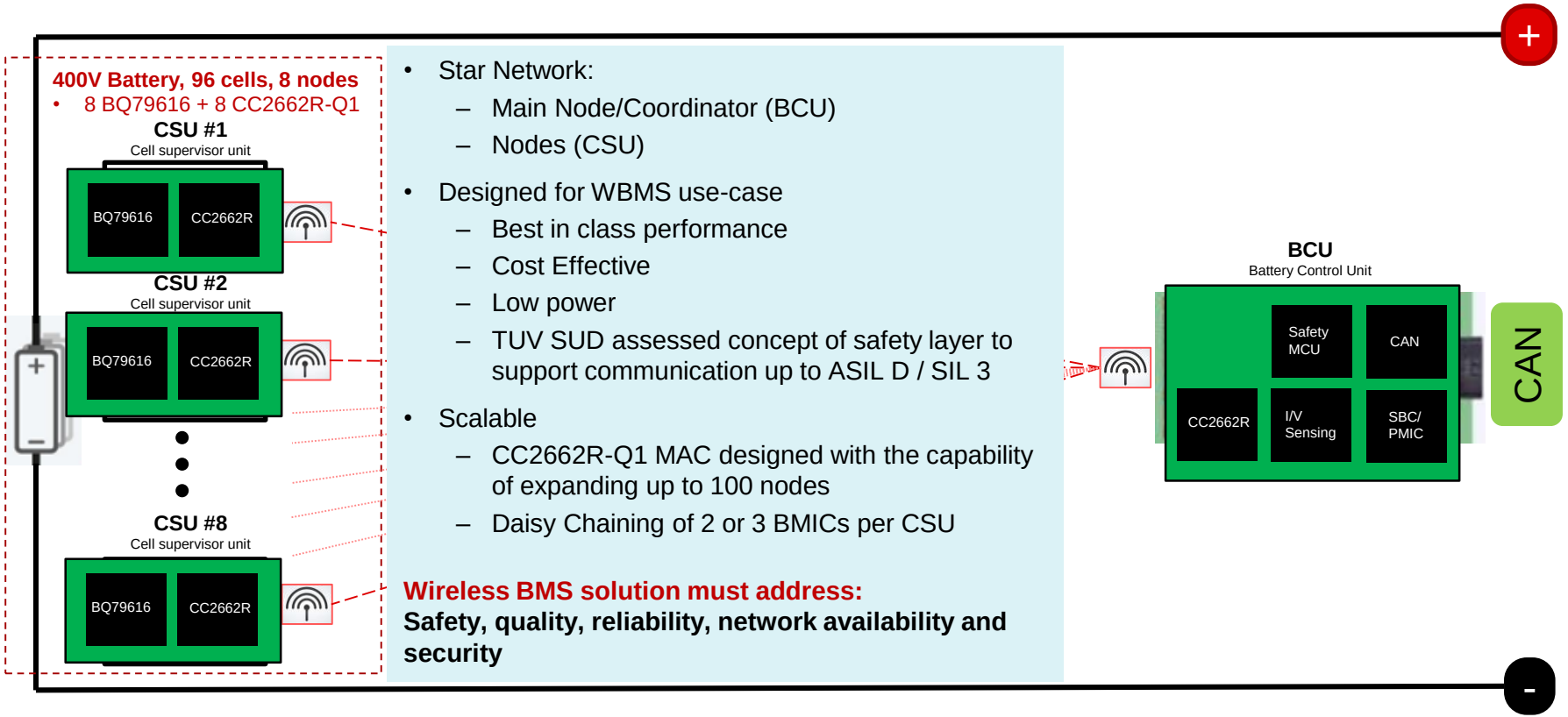
- Samples available today

TI WBMS | Solution elements



- Component Level
  - BQ79x1x-Q1 is an ASIL D compliant battery monitor – in production today
  - CC2662R-Q1 is an FS-QM wireless microcontroller – in production today
  - WBMS protocol is systematically compliant to ASIL D
- Scalable software solution covering the elements of WBMS
  - WBMS SDK (Network SW) in production now
- System level:
  - TI technical concept is unique among competitors
  - Built on the above components
  - TÜV SÜD assessed concept of safety layer to support communication up to ASIL D /SIL 3

TI WBMS | Solution elements

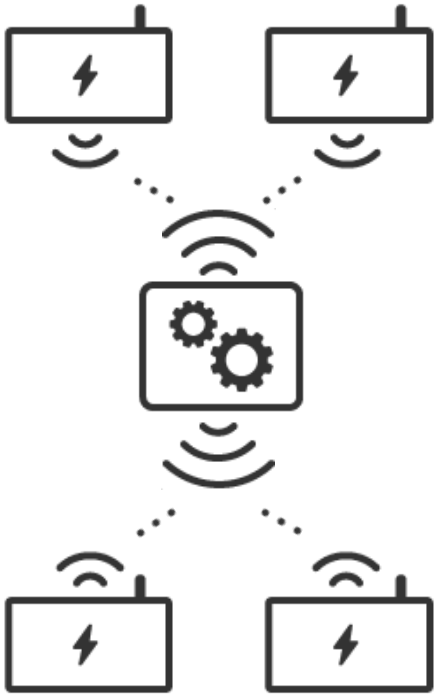


- Star Network:
  - Main Node/Coordinator (BCU)
  - Nodes (CSU)
- Designed for WBMS use-case
  - Best in class performance
  - Cost Effective
  - Low power
  - TUV SUD assessed concept of safety layer to support communication up to ASIL D / SIL 3
- Scalable
  - CC2662R-Q1 MAC designed with the capability of expanding up to 100 nodes
  - Daisy Chaining of 2 or 3 BMICs per CSU

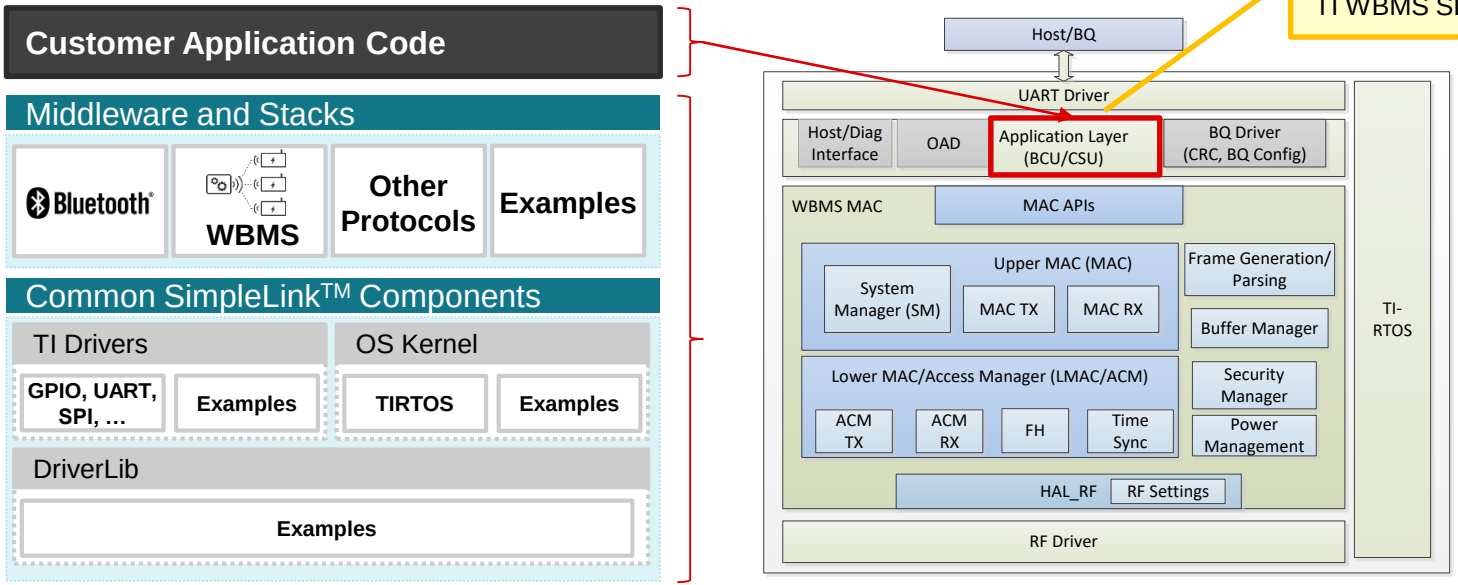
Wireless BMS solution must address:
Safety, quality, reliability, network availability and security

TI WBMS | Protocol highlights

Commercial	
• Low cost systems solution	No TI SW licensing fees
• Multi sourcing strategy	Multiple int/ext fab + assembly sites (LFAB, Clark, CDAT)
Performance	
• Wireless throughput	Up to 1.2 Mbps
• Scalability	100 nodes supported
• Low latency	< 2 ms per node / 16ms (1 main / 8 device)
• Link robustness	> 99.999% availability /< 10E-7 PER
• Link budget	103.6 dBm
• Fastest network reforming	<110 ms
• Low power	<100uA Wireless Main / <70-uA/device keep alive
Safety	
• Solution assessed by TÜV-SÜD	WBMS concept to demo support for system-level functional safety communication layer up to ASIL D
Product Readiness	
• Silicon and ref design available **today**	AEC Q100 Grade 2, EMC tested, FCC ready
• Free production-ready SW **today**	Developed against ISO26262 ASIL D



TI WBMS | Software ecosystem

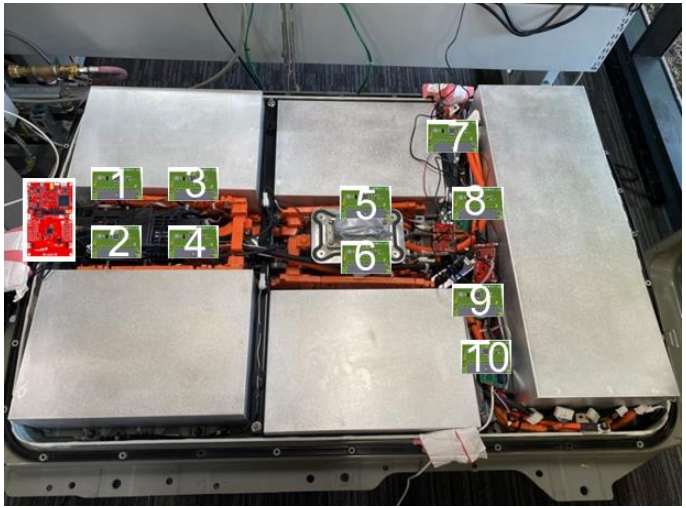


- The TI WBMS extends the TI SimpleLink Software ecosystem giving a ready-to-use, production ready out-of-the box product providing:
  - Full application code
  - Examples that allow you to go from boards to an executing network in minutes.
- The application layer in the TI WBMS SDK provides everything required to create a WBMS solution and still gives space to add future innovations.

TI WBMS | RF link budget

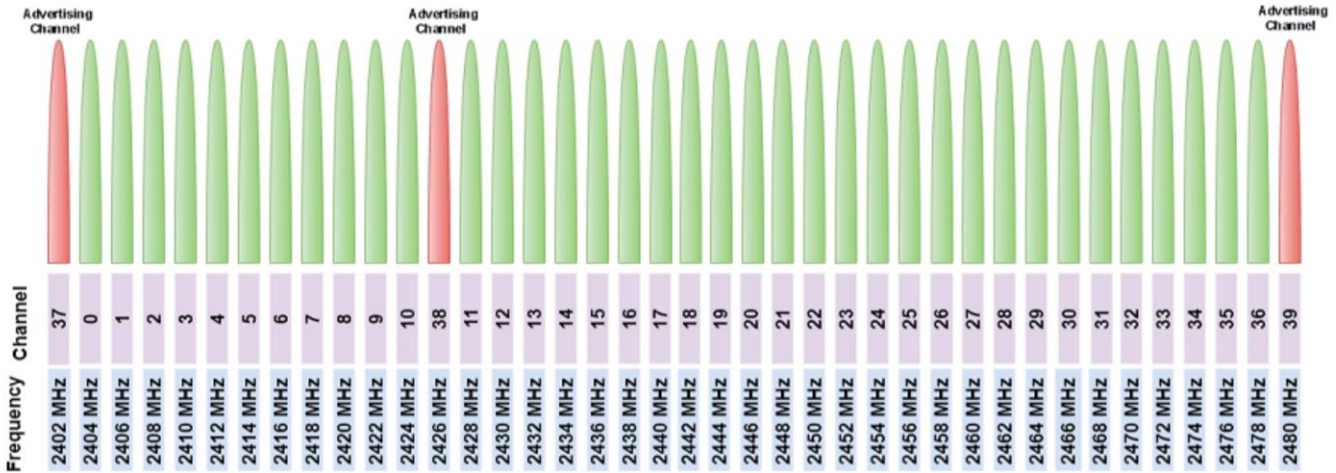
- RF link budget is one of the key concerns within Wireless BMS
  - The largest uncertainty is related to the RF channel path loss inside the battery compartment due to multipath and signal reflections from battery cells, battery compartment walls and wiring.
  - 3D RF modelling and simulations offer a starting point for determining path loss (attenuation) between two nodes
  - The physical distance will vary across the network CSUs and is not modeled in the link budget calculation table below.
- **TI WBMS RF solution RF link budget: 103.6 dB**

Device		**CC2662R-Q1**
Parameter	**Units**	
Distance	m	1,0
TX Output Power	dBm	5,0
TX Antenna Gain	dBi	3,3
Path Loss	dB	-80,0
RX Antenna Gain	dBi	3,3
Expected RX Signal Level	dBm	-67,4
Sensitivity	dBm	-92,0
Link Margin	dB	24,6



TI WBMS | Radio frequency channels

The TI WBMS frequency hopping protocol uses 37 channels, i.e. the same 2.4-GHz ISM band channels as the Bluetooth Low Energy (BLE) apart from the 3 BLE advertisement channels. The BLE advertisement channels are excluded from the WBMS protocol to minimize interference.



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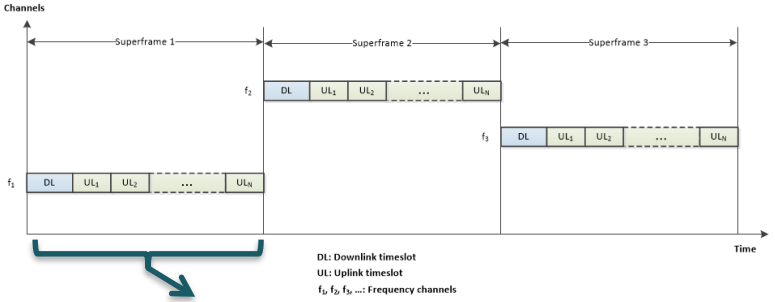
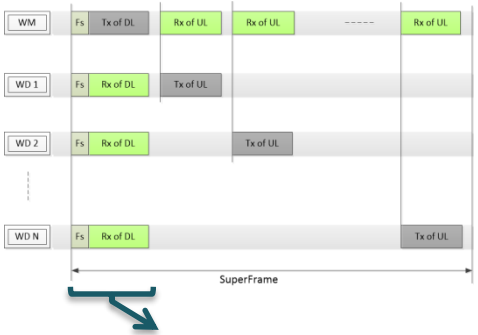
TI WBMS | TS + FH

- TI WBMS is a time slotted (TS), frequency-hopping (FH) protocol.
- Each time slotted frame is called a “WBMS superframe”.
- Frames in each timeslot contain solely uplink (UL) or downlink (DL) “WBMS frames”
- A single WBMS frame serves as a **container** carrying a “BQ frame” as a payload





Octet	1								2								3								4							
Bit	0	1	2	3	4	5	6	7	0	1	2	3	4	5	6	7	0	1	2	3	4	5	6	7	0	1	2	3	4	5	6	7
0	Preamble																DataSyncword															
4	DataSyncword												Length				MasterID								Frame Control							
8	SequenceNr								Security Header																							
12	Security Header																Ack								TrackN							
16	Payload																															
	Payload																															
...	MIC																															
256	CRC-32																															

INIT[7:0]	DEV ADR[7:0]	REG ADR[15:8]	REG ADR[7:0]	DATA MSB[7:0]	...	DATA LSB[7:0]	CRC[15:8]	CRC[7:0]

WBMS protocols | Two protocols

WBMS protocol:

- “Transmission code” per IEC62280
- Closed, developed in house
- SW follows ISO26262 compliant process

Octet	1								2								3								4							
Bit	0	1	2	3	4	5	6	7	0	1	2	3	4	5	6	7	0	1	2	3	4	5	6	7	0	1	2	3	4	5	6	7
0	Preamble																DataSyncword															
4	DataSyncword																Length								Frame Control							
8	Frame Control								MasterID								Source Address															
12	SequenceNr								Ack								SecurityHeader															
16	SecurityHeader																								Payload							
…	Payload								MIC																							
256	MIC								CRC-32																							
260	CRC-32																															

BQ protocol:

- Implemented in BQ79616-Q1 state machine
- Request-response
- BQ79616-Q1 datasheet for details
- Contact TI for more info on roadmap for BQ devices

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TI WBMS safety | Black channel

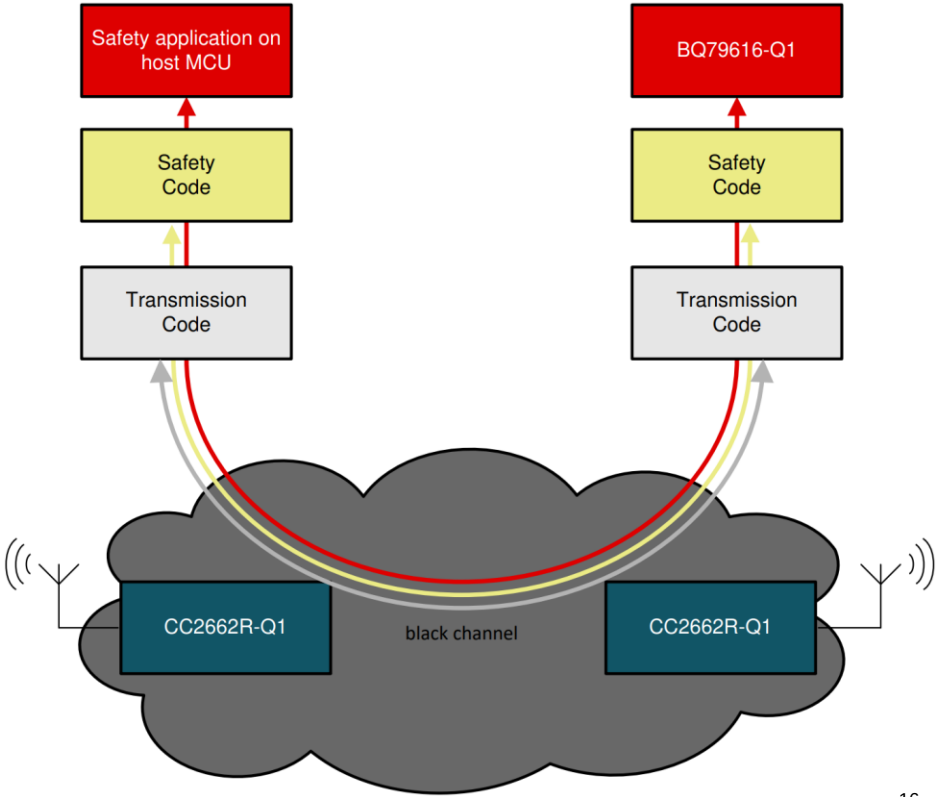
IEC62280:2014, Annex C.4

Transmission system may use error detection mechanisms that runs on non-compliant HW to improve overall error rate of the transmission media

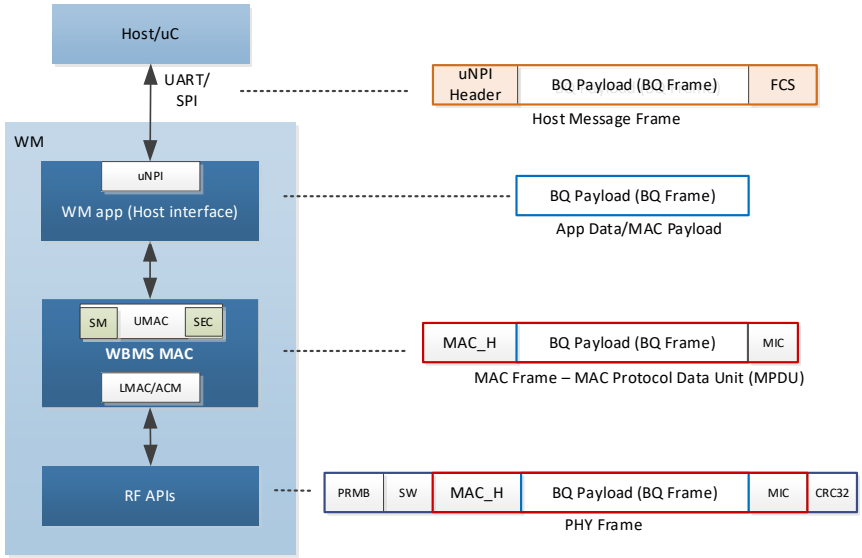
Applied in WBMS:

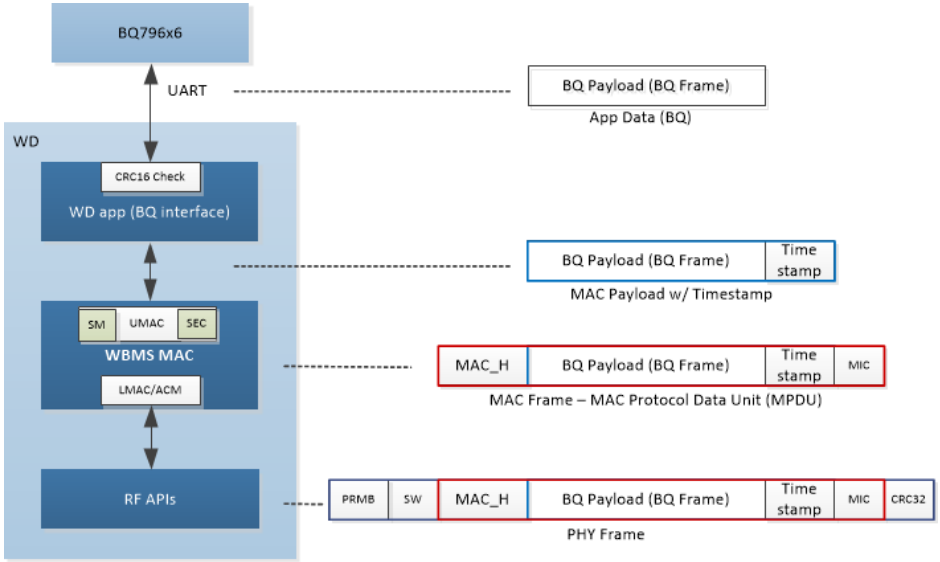
TI proprietary WBMS communication protocol overlaying the safety code

- Safety code and transmission code layered
- Both implement error detection mechanisms
- Conveys “containers” of original wired BMS protocol (“BQ protocol”)



TI WBMS | Data frame construction





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TI WBMS | Software features

Ease of manufacturing

- Integrated RF diags. module to enable test + compliance
- Controlled network joining by unique ID
- Non-permanent network joining for test

Ease of repair

- Repair support of a BMS enclosure when the network is to be maintained but either:
  - Wireless main replacement
  - Wireless device(s) replacement

Auto resync

- Easily enable resync of nodes extremely rare desync events
- Support for WD to automatically resync.
- Support for WM to automatically or when commanded to resync.

Daisy chain

- Support for daisy-chaining multiple BQ79x1x-Q1 devices off a single wireless device (typically 2-3 BMICs per wireless device)

And more! Contact your TI Sales team if you want to know more info on SW features and SW roadmap!

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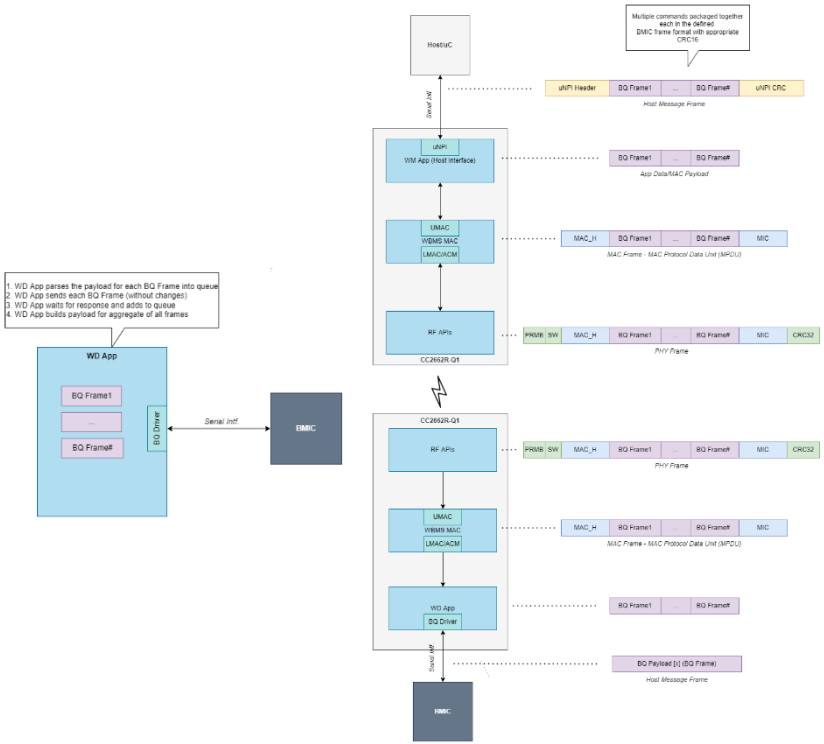
TI WBMS | Wireless BQ command aggregation



- TI is enabling “WBMS command aggregation” to accelerate system performance and achieve goals.
- The TI WBMS allows for packing multiple BMIC commands into a payload
- Enables more efficient use of radio transmission payloads to allow quicker assessment of FDTI and SoC/SoH

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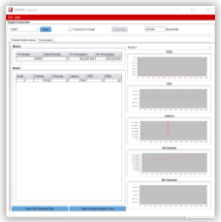
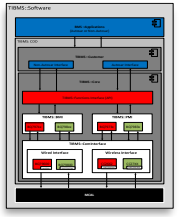
TI WBMS | Development lifecycle



MicroNova Software and Systems

Fault emulator
Wired/Wireless
Same interface

KPIT GRC

AUTOSAR CDD
Wired/Wireless
Same API's

CADFEM AVL

3D RF Simulation

Prototype

Quickly evaluate the capability of TI's WBMS offering using our hardware and software demonstrators.

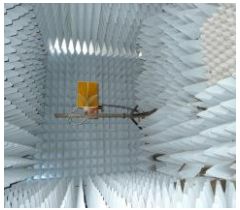
Demonstrate

Work with TI and TI's partners to build out a comprehensive solution.

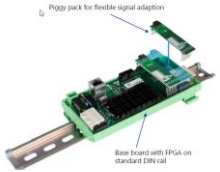
Productize

Launch a successful platform.

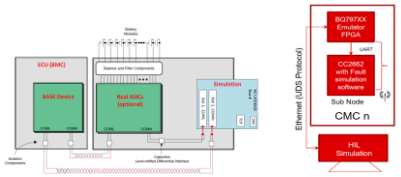
Test and evaluate your solution using our state-of-the-art RF evaluation chambers and fault injection capabilities.



TI RF Lab



Emulator



Advanced EVM

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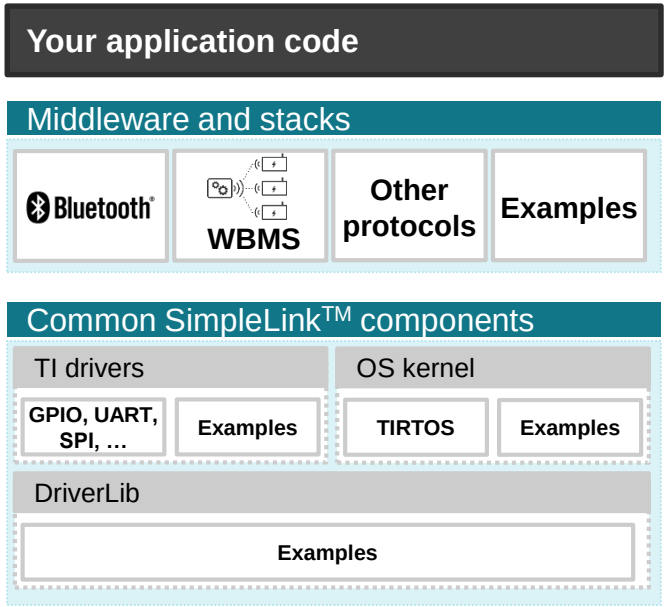
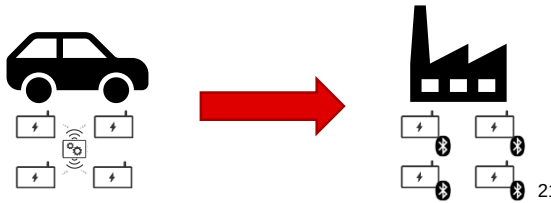
TI WBMS | Second life

- The CC2662R-Q1 contains a software defined radio running the SimpleLink SDK.

- This common software enables your product to support:
  - WBMS for in-pack
  - Non-WBMS protocols (e.g. BLE) for second life
  - Futureproof solution – high flexibility for roadmap features
    - Expect EU legislation in the future to require second life

- TI's robust platform plus extensive SDK enables reuse, simplifies development and enables a quicker time to market.





TI WBMS | Next steps

Wireless connection between battery packs and battery management system to replace traditional, wired connections

Why Wireless BMS?

Increases EV Range	• Reduces overall vehicle weight by replacing heavy battery-management wiring with high-reliable, secure wireless connections
Improves Time to Market	• Eliminates development costs & complexity associated with routing a labyrinth of battery-management cabling
Enhances Vehicle Scalability	• Manufacturers can address multiple EV vehicle and market segments with a single modular wBMS platform
Reduces Warranty Expense	• Removes the need for costly repairs due to common cable breaks and harness failures in traditional wired systems

Getting started

1. Request SDK download
2. Request wBMS development kit
3. Download documentation
4. Request functional safety assessment

Three questions to ask about wireless BMS for hybrid and electric vehicles

Why wireless for battery management systems (BMS)?

CC2662R-Q1 Automotive qualified SimpleLink™ wireless MCU for use in wireless battery management systems

BQ79616-Q1 Automotive ASIL-D compliant battery monitor for use in wireless battery management systems

Fixed-low-latency protocol with high throughput and high reliability for ultra-low packet error rate

Why TI?

Best network availability	• TI's wireless protocol for BMS via the CC2662R-Q1 MCU offers the industry's highest network availability greater than 99.999%
System-level functional safety compliance	• Industry's first TÜV SÜD assessed safety concept for wBMS • System-level ASIL-D compliance • AEC-Q100 functional safety Quality-Managed wireless MCU • AEC-Q100 functional safety compliant battery monitor
Flexible battery architecture	• Industry-best scalable solution with support for up to 100 nodes
Low power	

Thank You !

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