

Bluetooth 5 – Five things to consider for designing Smart Edge Devices

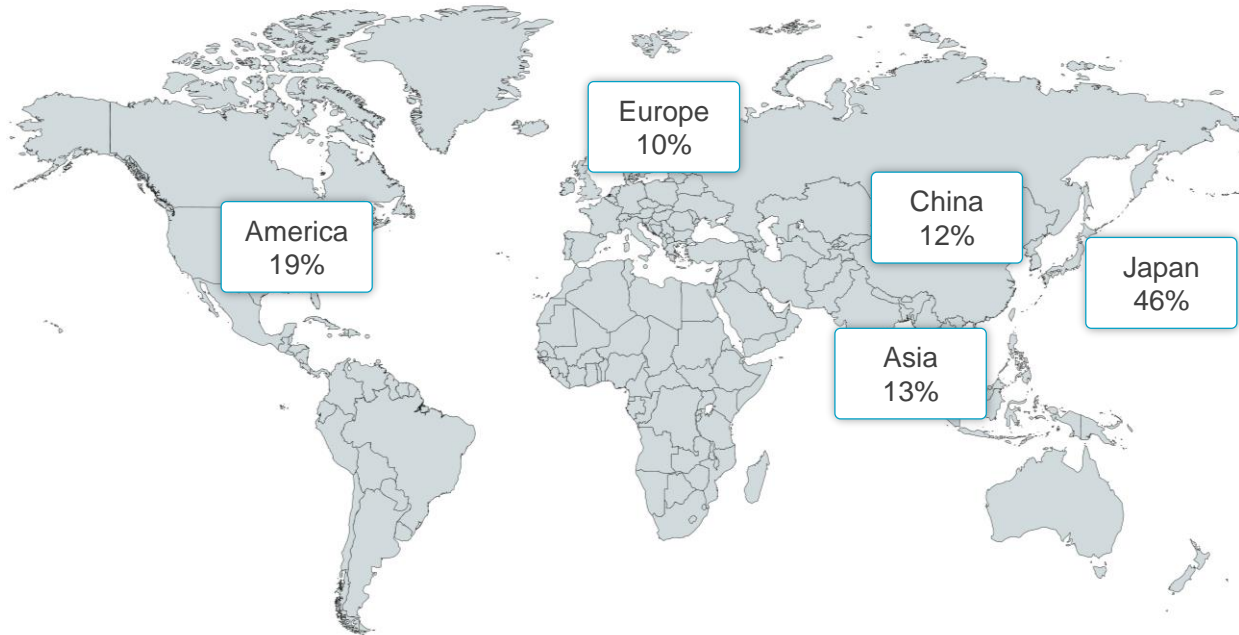
Chetan Joshi

Pascal Meier

- **Panasonic – A brief introduction**
-
- **IoT on the edge**
 - **Bluetooth Low Energy basics**
 - **Bluetooth 5 - Five things to consider for designing Smart Edge Devices**
-
- **Panasonic Bluetooth 5.0 - Module lineup**



Panasonic – a brief introduction



€ **62.52 billion**
Consolidated sales*

Panasonic is one of the world's leading electronic manufacturers with a century of experience.

271,869 employees work for Panasonic globally.

*Consolidated sales after elimination and adjustments based on average exchange rate 2018: 1 € = 128 JPY



€ 3.8 billion
Global Investment*

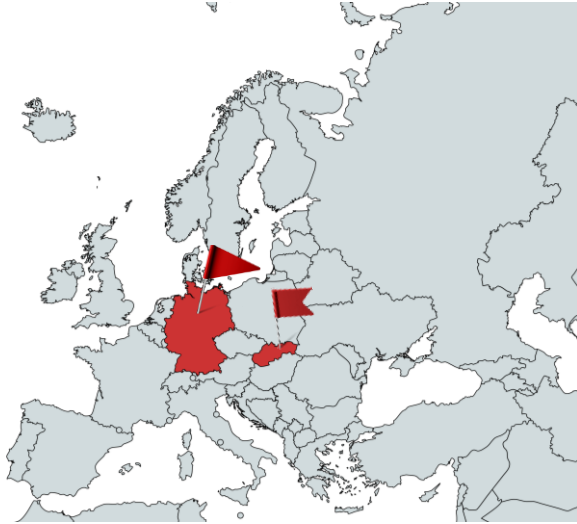
Panasonic invested **6%** of their net sales in R&D.

Panasonic ranked **10th** in The Forbes Global 2000 List, **The World's Best Regarded Companies in 2017** by Forbes magazine.

*Based on average exchange rate 2018:
1 € = 128 JPY

Company Overview

6 locations
4 legal entities
4 countries
2275 employees



Lüneburg, GER



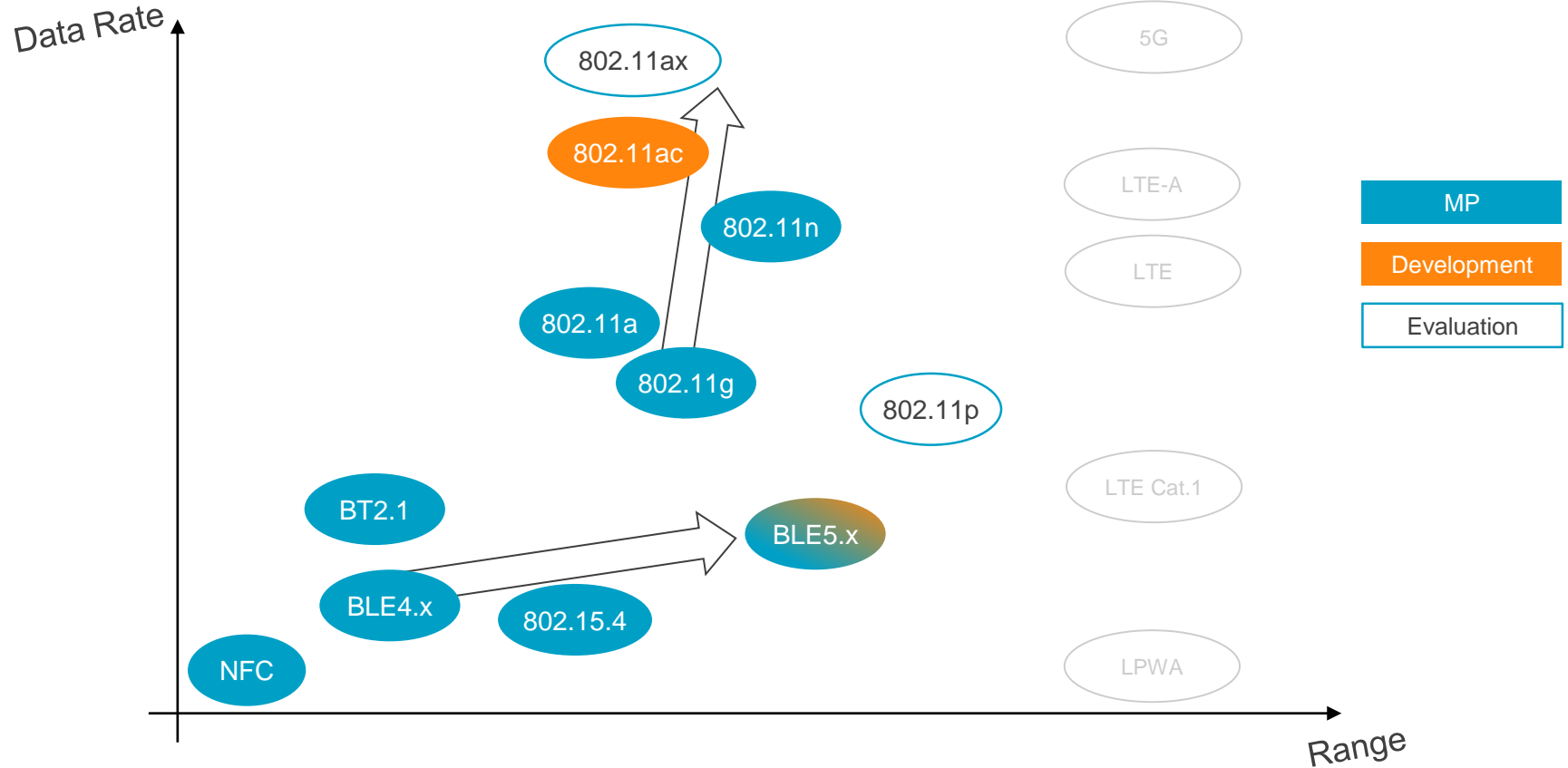
Established	1984
Head of site	U.Bachsmann, T.Horio
Employees	348
Functions	HQ, Development, FAE, Marketing

Stara Lubovna,SK



Established	1997
Head of site	U.Bachsmann, S.Vojtas
Employees	540
Functions	Production
Products	Wireless Modules, Control boards, AMP,

Wireless Technology Overview



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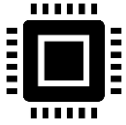


Intelligence



Ubiquitous Computing – everyday objects embedded with local intelligence

IoT on the Edge – Understanding the Edge Device



Compute power



Power Consumption



Data generation and analysis capacity



Real-Time Response



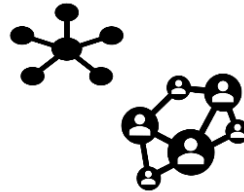
Connectivity



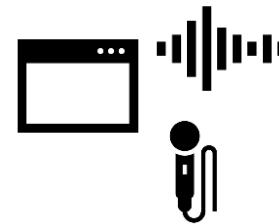
Data back-up capability



Data and communication security



Machine to Machine (M2M) communication



Human to Machine Interface capabilities (HMI)

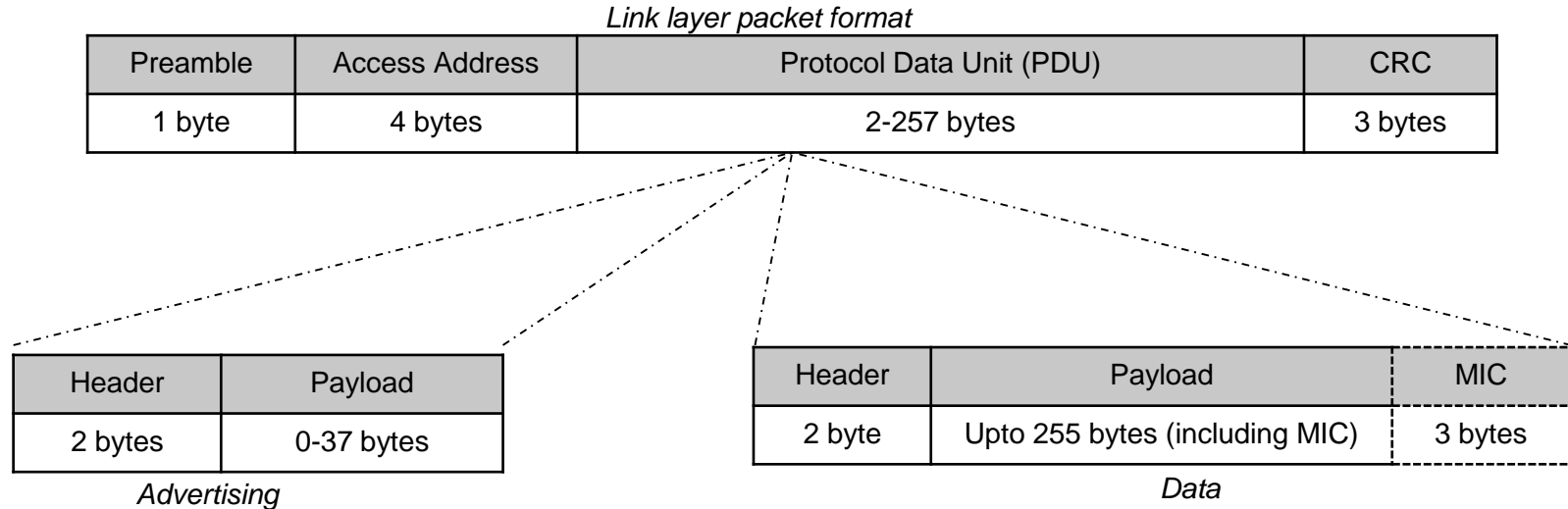


Price

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- Low complexity FM modulated carrier in 2.4 GHz ISM band (2400-2483.5 MHz)
- Adaptive Frequency Hopping transceiver to combat interference
- Physical layer symbol rate original defined as 1 Msym/sec; now known as LE 1M PHY
- Output power limited to 10dBm.
- Two multiple access schemes
 - FDMA: 40 different physical channels – 37 data channels, 3 advertising channels
 - TDMA: Physical channel divided in to time units called **events**. Polling scheme for events to occur at predetermined time.

- Bluetooth Low Energy packet structure:



- Packets contain Cyclic Redundancy Check (CRC) error detection
 - Erroneous packages aren't acknowledged at Rx, No ACK indication sent
 - Upon missing ACK event, Tx retransmits the lost packet

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- **Bluetooth 5 - Five things to consider for designing Smart Edge Devices**
 1. Features
 - I. Bluetooth 5.0 new features
 - II. Bluetooth 5.1 & further
 2. Topologies
 3. Trade-offs
 4. Security
 5. Bluetooth in a multiprotocol scenario

- **Panasonic Bluetooth 5.0 - Module lineup**

- Standard launched in December 2016
- New features added in Bluetooth 5.0:

A. Extended Advertising

B. New PHY's

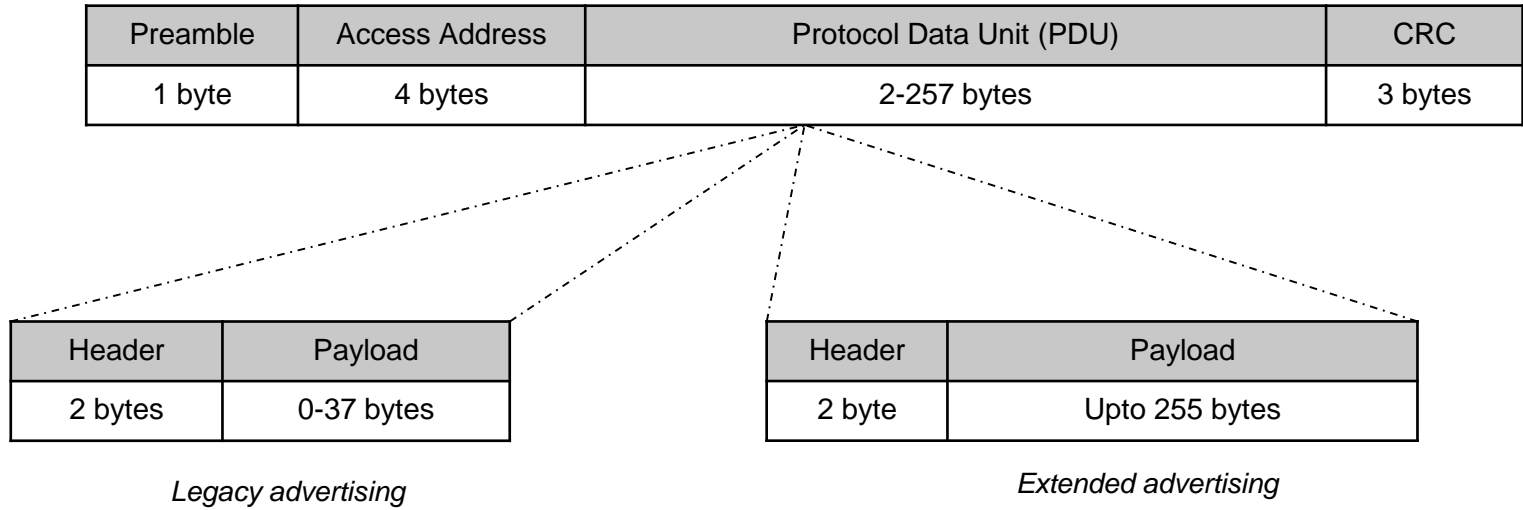
C. And more

LE Channel Selection Algorithm #2 – allows for a larger set of frequency hopping sequences

Slot Availability mask – allows for a better coexistence with LTE cellular networks

I. Bluetooth 5.0 features – New improved advertising

- In addition to 3 primary advertising channels – 37 secondary channels (previously reserved for sending data)
- High duty cycle non-connectable advertising event possible in broadcast mode
- New larger size of advertising PDU for broadcast only events: Up to 255 bytes.



I. Bluetooth 5.0 features – New PHY's

- Un-coded 2M PHY:

Link layer packet format

Preamble	Access Address	Protocol Data Unit (PDU)	CRC
2 bytes	4 bytes	2-257 bytes	3 bytes

Supports higher throughput thanks to a two times the modulation rate

- LE Coded PHY:

Uncoded	FEC1 (S=8)			FEC2 (S=2 or 8)		
Preamble	Access Address	CI	TERM1	Protocol Data Unit (PDU)	CRC	TERM2
80 (bits)	32	2	3	16-2056	24	3

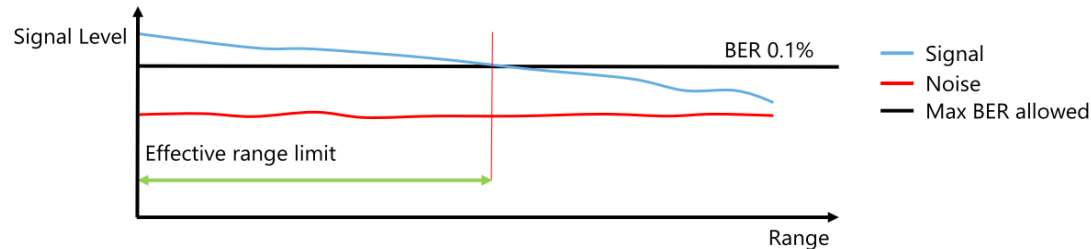
Packets take between 462 and 17040 μ s to transmit over LE 1MPhy.

Both PHY's are mutually exclusive for a given connection between two devices

I. Bluetooth 5.0 New Features: Understanding Coded PHY

- After CRC check, erroneous packets aren't rejected
- Error correction is done by adding Forward Error Correction (FEC)
- Additional redundant bits added to the transmitted packets.
- On receiver side, FEC algorithm determines the correct value of erroneous bits
- Throughput depends on value of S (2 or 8)
 - S = 2 → 1 symbol coded in 2 bits – 500kbps
 - S = 8 → 1 symbol coded in 8 bits – 125kbps

Uncoded	FEC1 (S=8)			FEC2 (S=2 or 8)		
Preamble	Access Address	CI	TERM1	Protocol Data Unit (PDU)	CRC	TERM2
80 (bits)	32	2	3	16-2056	24	3



I. Bluetooth 5.0 New Features: Important to remember

- Devices can be compliant to Bluetooth 5.0 core specification without having optional features.
- Extended Advertising & new PHY's are optional - both devices in connection need to support optional features

- Standard Launched in January 2019
- New features include:
 - Periodic Advertising Sync Transfer

The advertiser and scanner wake in synchronisation to listen to the advertisement go to sleep.
e.g. Bluetooth sensor data

- Direction finding using Angle of Arrival (AoA) or Angle of Departure (AoD) techniques.

II. Bluetooth 5.1 & Further: Direction Finding

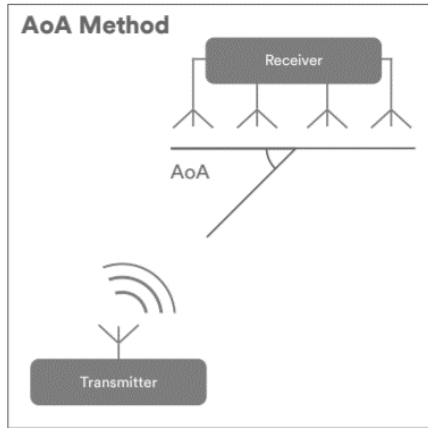
- Guessing direction of a signal in 2D or 3D plane using phase difference of the signal.
- Phase retrieved using IQ sampling at receiver.
- New link layer packet as defined in 5.1:

Preamble	Access Address	Protocol Data Unit (PDU)	CRC	CTE (opt.)
1/2 bytes	4 bytes	2-257 bytes	3 bytes	16 to 160µs [111111...111]

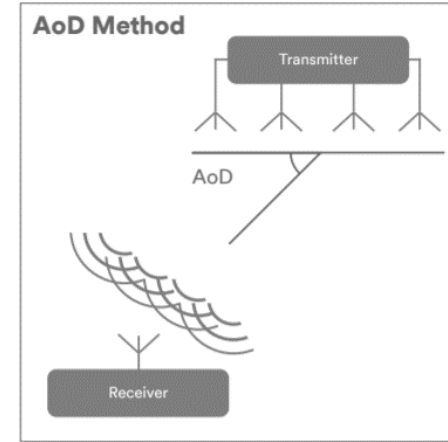
- IQ sampling susceptible to change in wavelength: CTE: Constant Tone Extension → series of unwhitened 1's.
- CRC on direction finding packets – CTE not taken in account
- MIC on direction finding packets – CTE not taken in account
- Only works on un-coded PHY's: LE 1M/2M → No coded PHY
- Whitening: Direction finding packets are exempted from scrambling to allow sending long sequences of 1's.

II. Bluetooth 5.1 & Further: Direction Finding

- Two possible methods of direction finding using Bluetooth 5.1



Connection oriented;
Multiple antennae on Rx



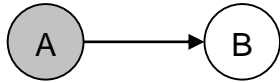
Broadcast oriented;
Multiple antennae on Tx

- Direction finding requires at least one device to be a multiple antenna system
- Changes announced by SIG only affect LE controllers. Application profiles to be available in future.
- Hardware is available on the market

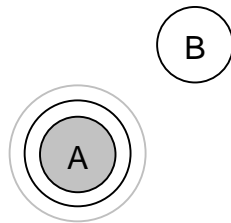
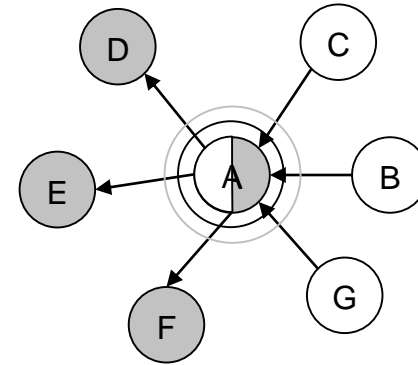
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2. Topologies

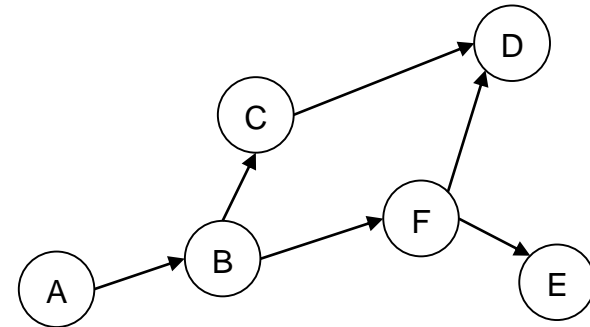
Point to Point



Simultaneous connections



Broadcast



Mesh via managed flooding

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3. Trade-offs

1. Range vs speed:

PHY	Range	Speed (theoretical)
Coded PHY	~1 km	125kbps
2M PHY	~ x m	2Mbps

2. Current consumption vs. RF output

As an example on PAN1780 – Non connectable advertisement event

Payload: 31 bytes

Advertising interval: 20 ms

RF output power	Average current
0 dBm	466 μ A
8 dBm	901 μ A

3. Platform cost vs features

Module	RAM / Flash	Simultaneous connections
PAN1762	128 kB/128 kB	1 (Peripheral or central)
PAN1780	256 kB / 1MB	20 (Peripheral, Central & Adv)

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 4. Security
 - I. Features
 - II. Risks
 - III. Mitigation strategies
 5. Bluetooth in a multiprotocol scenario

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- Bluetooth protocol security features:
 1. Pairing: Process for creating one or more shared secret keys
 2. Bonding: Using stored keys for subsequent connections in a trusted device pair
 3. Authentication: Verification that the two devices have the same keys
 4. Encryption: Maintains message confidentiality
 5. Integrity: Protects against message forgeries

- LE privacy feature:
 - Reducing ability to track LE devices by changing Bluetooth Device Address frequently

4. Security: Mitigation Strategies

- Grandpa's advice: When not using, switch your Bluetooth off
- Adopt the optimal security strategies available in the protocol
- Use of secure element in parallel to Bluetooth device to store keys
- Using hardware with integrated hardware cryptographic accelerators & other features
- Work in close partnership with device vendor on potential vulnerabilities

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IoT on the edge:

1.Features

2.Topologies

3.Trade-offs

4.Security

5.Bluetooth in a multiprotocol scenario

- **Panasonic Bluetooth 5.0 - Module lineup**

Bluetooth + WiFi

- Channel Selection Algorithm #2
- Collocated shared Radios – Time Division Duplexing (TDD)
- Coexistence:
 - Adaptive frequency Hopping
 - Proprietary techniques

Bluetooth + 802.15.4

- Thread/Zigbee
- Bluetooth acts as a gateway device
- Dynamic Channel Selection on MAC (Energy detection)
- CSMA-CA
- MWS Coexistence

Bluetooth + Cellular Radio

- Co-existence measures with MWS to combat high interference in 2.4 GHz ISM
- Bluetooth specifies :
 - Filtering
 - Messaging & signaling mechanisms
- Slot Availability mask

The background is a solid dark blue color. There are several light blue, semi-transparent abstract shapes: a vertical bar on the left side, and a large, stylized 'N' shape at the bottom center.

Bluetooth 5.0 Panasonic Module Lineup

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 1. Advantages of modules
 2. Bluetooth 5 solutions from Panasonic

Integrated Circuit

- > Different vendors and partners

Software

- > Host or Standalone Mode
- > Panasonic Command Set or
 - > IC vendor SDK
 - > Pre-flashed on request

Shield

- > Fullfil Certification requirements
- > 100% traceability



Passive Components

- > Reduce BOM and procurement costs
- > Easier design-in process

Antenna

- > Integrated chip antenna
- > Module placement reference for best performance










Printed Circuit Board

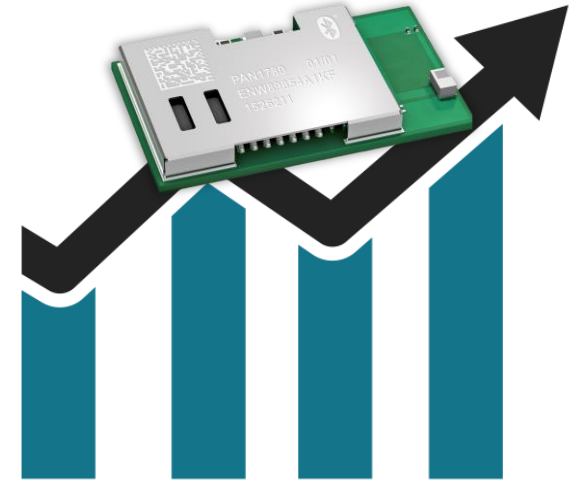
- > Less customer PCB layers
- > Reduce production costs through 1 pretested component

Certifications

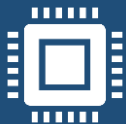
- > (Pre-) certified modules reducing costs, time, man-power
- > Europe, USA, Canada, Japan, China, South Korea

Module vs. Chip Design – Benefits at a Glance

	Time-to-market	Faster development times	✓
	Certification	Reduced certification costs	✓
	RF design	Lower RF team needs Less board design iterations	✓
	Size	Saves board area	✓
	Procurement	Reduced operational costs	✓
	Assembly	Reduced production costs	✓
	Test	Reduced production costs	✓
	Quality	Increased quality	✓
	Yield loss	Reduced production cost	✓



PAN1780

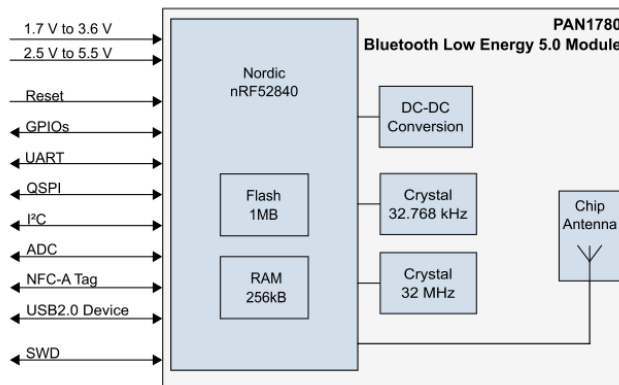


Supported 5.0

- LE 2 Mbps high-speed PHY & long range coded PHY
- LE advertising extensions (advertising on 40 channels total)
- Channel selection algorithm #2
- LE secure connections
- Over-the-air update of application software
- Up to 20 simultaneous LE connections
- Bluetooth Mesh

Additional features

- ARM® TrustZone® Cryptocell 310
- Type 2 Near Field Communication (NFC-A)
- Up to 4 SPI, 2 I²C, 2 UART, 4 PWM, 8 ADC, 1 USB 2.0



Host, Standalone	Nordic SDK
ARM Cortex-M4F	
1 MB <i>Flash</i>	256 kB <i>RAM</i>
+8 dBm <i>output power</i>	-103 dBm <i>sensitivity</i>
Chip <i>antenna</i>	CE, FCC, IC under preparation <i>certifications</i>
15.6 x 8.7 x 2.1 [mm] <i>size</i>	

✓ SoC

- No. 1 Bluetooth IC supplier in terms of new designs registered at BT SIG every year.
- nRF52840: An established « **high-end** » Bluetooth platform in mass production – far ahead of competition in relevant market segment.

✓ Module

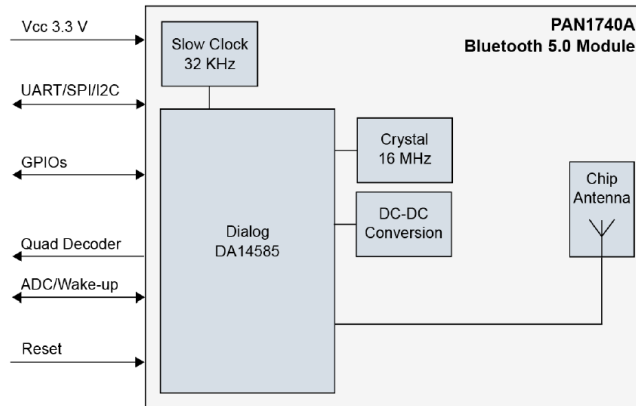
- Fully certified module with integrated antenna in a very small form factor
- Great price & support guaranteed by Panasonic


PAN1740A



Features

- 8 simultaneous Bluetooth LE connections
- Power consumption 4.9mA Rx and Tx
- Faster boot-time (<50ms) with wide Voltage input (0.9V, 1.8V)
- GPIO, UART, SPI+, I²C, 3-axis QD, ADC, PDM/PCM



 DA14585	
Host, Standalone <i>mode</i>	Dialog SDK
ARM Cortex-M0	
64kB <i>OTP</i>	96kB <i>SRAM</i>
+0 dBm <i>output power</i>	-93 dBm <i>sensitivity</i>
Chip <i>antenna</i>	Under preparation <i>certifications</i>
9.0 x 9.5 x 1.8 [mm] <i>size</i>	

✓ SoC

- Bluetooth 5.0 core – support for extended advertising – is sufficient for most IoT use cases.
- Can hold multiple connections simultaneously

✓ Module

- Fully certified module with integrated antenna
- Small size - ideal for projects with size constraints
- Cost effective alternative to High End Bluetooth 5.0 & BLE Mesh modules

Which one do I need?



PAN1780

High Performance



PAN1740A

Small Size

RF Category		
5.0 core features	X	X
5.0 optional features		
• High duty cycle non-connectable advertising	X	X
• Efficient non-connectable advertising	X	X
• Long Range	X	
• High Throughput	X	
Bluetooth Mesh	X	
Link Budget	111dBm	93dBm
Microcontroller	ARM Cortex-M0	ARM Cortex-M4F
Memory	1MB Flash; 256KB RAM	64kB OTP; 96KB SRAM
Size [mm]	15.6 x 8.7 x 2.0	9.0 x 9.5 x 1.8
IC vendor		

PAN9026

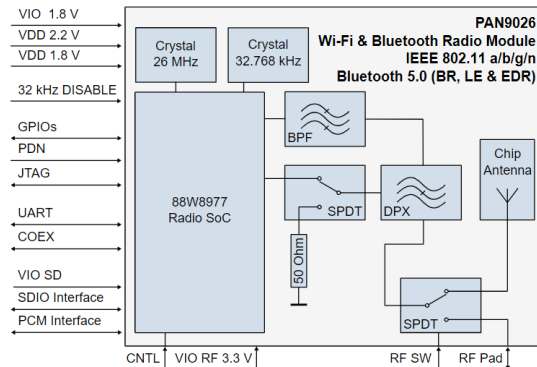


Features

- Simultaneous WLAN and Bluetooth operation with shared radio
- Simultaneous & power efficient operation of 2.4 & 5 GHz bands
- Flexibility of a selectable antenna with an SPDT switch
- Support for WPA3 – Personal security

Extract of supported 802.11 standards

- 802.11n – with maximum data rates of 150 Mbps (40 MHz)
- 802.11e – quality of service
- 802.11h – DFS Radar Pulse Detection
- 802.11i – enhanced security
- 802.11k – radio resource management
- 802.11mc – precise indoor location and navigation
- 802.11r – fast hand-off for AP roaming
- 802.11u – Hotspot 2.0 (STA Mode Only)
- 802.11s – Mesh over WiFi (μAP and STA functions)



 88W8977	
HCI	Linux Driver
SDIO 3.0, HS UART <i>interfaces</i>	
+17 dBm	-98 dBm
<i>output power</i>	<i>sensitivity</i>
Chip antenna	CE RED, FCC, IC certifications
17.5 x 10.0 x 2.6 [mm]	
<i>size</i>	

Bluetooth specific features

- Bluetooth Classic
 - Basic Rate
 - Enhanced Data Rate
- Bluetooth Low Energy 5.0
 - SAM - Slot Availability Masks (BT)
 - High duty cycle non-connectable advertising
 - Support for Direction Finding: Connection Oriented AoA

Additional features

- Concurrent Bluetooth Classic and Low Energy operation
- Linux Drivers available for Bluetooth operation over SDIO or UART
- Simultaneous connections: Up to 16 simultaneous master and slave connections



HCI Layer Support

- Full support up to HCI layer
 - choice of profile stack left to user
- Supported stacks: BlueZ, BlueSDK or other commercially available stacks



Martin Keenan

Technical Director,
Avnet Abacus

E-Mail: martin.keenan@avnet-abacus.eu

Further resources to support your designs...

- Evaluation kits
- Product information
- Design guides
- Software and developer guides

Reliability and Availability

Product specific features

Easy-to-use

Business Model Flexibility

One-Point of Support

Panasonic

Long lasting partnerships with IC supplier and software provider

Certifications: CE, FCC, IC

European Product

Solutions from scratch

Fast decision making