Bluetooth low energy

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Introduction

Bluetooth low energy is the latest addition to the Bluetooth family. This presentation will give an insight into:

- What is Bluetooth low energy?
- Bluetooth low energy fundamentals
- Market Segments
- Qualification program
- Nordic’s Bluetooth low energy offering – uBlue

Disclaimer
Bluetooth low energy specification and products are under development and specification and schedule are subject to change.
Introduction

Bluetooth Low Energy

"Create a ubiquitous RF enabled informational environment"
Purpose of Bluetooth low energy

*Bluetooth low energy wireless technology is an open low energy, short range radio technology*

Key Benefits
- low power consumption
- small size
- connectivity to mobile phones
- low cost
- robust, efficient
- multi-vendor interoperability
- global availability, license free
Principles of ultra low power operation
Low duty cycle operation and fast connections

Low duty cycle, short packages and high on air data rate
- Connection intervals from 3ms to 4s+
- Short data packets – up to 31 bytes payload
- 1 Mbps on-air data rate
- System spends most time in sleep mode
- RF is on only a small fraction of the time

Fast connection time
- Devices can connect in 3ms
- Allows for fast connection, send data and then disconnect
- System can spend most of the time in deep sleep
## Sport Fitness

### (Sensor) devices
- Odometer
- Pedometer
- Altimeter
- Body temperature
- Body liquid balance
- Heart rate monitor
- Acceleration
- Distance, speed etc.

### Host devices
- Sports watch
- Mobile phone
- Sports equipment
- Laptop/desktop

### Services
- Team fitness coaching
- Adventure sports team room
- Competition monitoring service

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![Image](image.jpg)

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**NORDIC SEMICONDUCTOR**
Medical/Home monitoring

<table>
<thead>
<tr>
<th>(Sensor) devices</th>
<th>Host devices</th>
<th>Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight scale</td>
<td>Mobile phone</td>
<td>Weight loss and fitness coaching</td>
</tr>
<tr>
<td>Blood pressure</td>
<td>Watch</td>
<td>Personal health record</td>
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<tr>
<td>Odometer</td>
<td>Laptop/desktop</td>
<td>Elderly monitoring service</td>
</tr>
<tr>
<td>Pedometer</td>
<td></td>
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<tr>
<td>Heart rate monitor</td>
<td></td>
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<tr>
<td>Glucose meter</td>
<td></td>
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<tr>
<td>Medication dispenser</td>
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</tbody>
</table>
Entertainment

<table>
<thead>
<tr>
<th>(Sensor) devices</th>
<th>Host devices</th>
<th>Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remote control of mobile devices (camcorder, MP3 player etc.)</td>
<td>Game console</td>
<td>Music stores</td>
</tr>
<tr>
<td>Gaming sensors</td>
<td>Mobile phone</td>
<td>Game stores</td>
</tr>
<tr>
<td>Remote control of home entertainment system (TV, stereo, DVD etc.)</td>
<td>MP3 player</td>
<td>Gaming communities</td>
</tr>
<tr>
<td></td>
<td>Laptop/desktop</td>
<td></td>
</tr>
</tbody>
</table>

- Remote control in intelligent clothing (MP3 player etc.)
Proximity

Proximity tags for mobile phones
- Alarm when phone out of range
- Lock phone when out of range

Proximity tags for other application
- Children in mall
- Computer security
- Keyless entry
- Keyless go

*Bluetooth* low energy Proximity profile
PUID

Use your watch to control MP3 player, mobile phone
Collect data from PAN
Get alerts
  - xx level low, time to take your medication
  - Your glucose level is xx
Dual Mode / Single Mode
Two implementation options

**Dual Mode**
- Combines BR/EDR and LE Bluetooth on a single chip
- Minimum delta cost vs. BR/EDR only
- Use anywhere where BR/EDR is used today

**Single Mode**
- Bluetooth low energy only
- The true ultra low power implementation
- Coin cell battery operation
- New class of devices

Mobile phones
Laptop PCs
Desktop PCs

Sports and fitness
Remote controls
Watches
Dual mode + single mode implementations

“Single Mode”
Bluetooth BR/EDR

- SPP
- RFCOM
- L2CAP
- Link Manager
- BR/EDR PHY

Dual Mode
Bluetooth 4.0

- SPP
- RFCOM
- L2CAP
- Link Manager
- BR/EDR + LE PHY

Single mode
Bluetooth low energy

- Attribute Profile
- Attribute Protocol
- L2CAP
- Link Layer
- LE PHY

Nordic Semiconductor
Bluetooth low energy system architecture

**Physical layer** – *transmits / receive bits*

**Link layer** – *packets and control*

**L2CAP** – *Link multiplexor*

**Generic Access Profile (GAP)** – *Discovery and link management*

**Security Manager Protocol (SMP)** – *Link security*

**Attribute Protocol (ATT)** – *Protocol for accessing data*

**Attribute Profile (GATT)** – *Data (attribute) organization*

**Profiles** – *Application specific protocol for communication between devices*
PHY – Channels 2

40 RF Channels

3 FIXED Channels for Advertising
   Used to broadcast data
   Connectable
   Discoverable
   Data Channels
   Used to send application data
   Adaptively Frequency Hopped

37 Dynamic Channels
   Used to send application data
   Adaptively Frequency Hopped
Link Layer - States

Scanning
- Listening for advertising packets ("Scanner")
- No RF activity

Advertising
- Transmitting advertising packets ("Broadcast") and listening and responding to responses

Standby
- No RF activity

Initiating
- Listening for advertising packets and responding to initiate a connection

Connecting
- Communicate with one or more slaves and control the timing of the connection.

Initiators becomes Masters
Advertisers becomes Slaves
Link Layer – Network Topology 1
Link Layer – Network Topology 2

- Initiator
- Slave
- Scanner
- Advertiser

Connection Request
Link Layer – Network Topology 3
Link Layer – Package Structure

All packets have same structure
- Preamble – 01010101 or 10101010
- Access Address – correlated 32 bit sequence
- Payload – actual data
- CRC – 24 bit CRC for robust bit error detection
  - CRC calculated over Payload

<table>
<thead>
<tr>
<th>Preamble</th>
<th>Access Address</th>
<th>Payload</th>
<th>CRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 byte</td>
<td>4 bytes</td>
<td>2 to 39 bytes</td>
<td>3 bytes</td>
</tr>
</tbody>
</table>
**HCI**

- Reuse existing HCI interface from BR
- Keeps existing HCI packet formats

- Added new LE Commands – for new functionality
  - Scanning / Advertising

- Reuses existing transports
  - e.g. UART / USB / SDIO / 3wire
Device capabilities
Profile roles

Bluetooth low energy defines 4 different profile roles

- **Corresponds to a minimum set of Link layer features and functionality to be compliant**
- **Broadcaster** – Perform broadcast advertisement to other devices
- **Observer** – Listen for broadcast advertisement from other devices
- **Peripheral** – Perform broadcast advertisement, connecting to other devices and serve as a slave in the connection
- **Central** - Listen for broadcast advertisement from other devices, initiate and serve as a master in a connection

A device *may* support one or multiple roles
Security Manager Protocol (SMP)

Performs Authentication and Key Management
  - Host function – gives more flexibility

Uses AES-128 as the encryption algorithm for security procedures

Defines protocol to setup a secure link
Attributes
The basic element of Bluetooth low energy communication

Attributes is simply ‘data’

- A value that has a meaning
- and permission
- and security requirements
- and is addressable by a handle

Attributes is composed of

- A value - the value itself, for example 25
- UUID – what the value mean, for example °C
- Handle – how to address it
Services
The key to use cases and interoperability

Bluetooth profiles
- Interface spec for communication between devices
- Ensures multivendor interoperability
- At least one profile is required for Bluetooth compliance
- Each profile provides support for a specific use-case

Bluetooth low energy:
- Instead of large profiles, many small services are available
- An application may need several services to support the required use-cases
# Bluetooth low energy profiles

## 2 of 2

<table>
<thead>
<tr>
<th>Profile</th>
<th>Brief</th>
<th>Core spec. version</th>
<th>Est. schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MedWG Profiles</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body temperature</td>
<td>Body temperature information</td>
<td>1.0</td>
<td>Q111</td>
</tr>
<tr>
<td>Blood pressure</td>
<td>Blood pressure information</td>
<td>1.0</td>
<td>Q410</td>
</tr>
<tr>
<td>Weight scale</td>
<td>Battery status and information</td>
<td>1.0</td>
<td>Q410</td>
</tr>
<tr>
<td>Glucose</td>
<td>Blood glucose level</td>
<td>1.0</td>
<td>Q410</td>
</tr>
<tr>
<td>Pulse Ox</td>
<td>Blood oxygen saturation</td>
<td>1.0</td>
<td>Q111</td>
</tr>
<tr>
<td>Heart rate</td>
<td>Heart rate information</td>
<td>1.0</td>
<td>Q310</td>
</tr>
<tr>
<td>Pedometer</td>
<td>Step counts</td>
<td>1.0</td>
<td>Q410</td>
</tr>
<tr>
<td>Speed</td>
<td>Speed information</td>
<td>1.0</td>
<td>Q410</td>
</tr>
<tr>
<td>Distance</td>
<td>Distance travelled</td>
<td>1.0</td>
<td>Q410</td>
</tr>
<tr>
<td>Cadence</td>
<td>Cycling cadence</td>
<td>1.0</td>
<td>Q410</td>
</tr>
<tr>
<td><strong>HID WG</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HID Profiles</td>
<td>Mouse, keyboard, game controller etc.</td>
<td>1.1</td>
<td>TBD</td>
</tr>
</tbody>
</table>
How do you qualify a Bluetooth low energy product
Just the same way as BR/EDR

Bluetooth Product Testing

Member Tests Product

Member Completes Product Test Plan

Member Completes Product Test Plan

Member Selects Product Features (PICS)

Member Obtains Bluetooth Design ID (i.e., B019999)

Member Starts Project On-line

Bluetooth Project Concept

Product Listing

Member Complexes Test Report

Member Submits Test Report to SIG

Member Completes PICS

Member Tests Product

Member Completes Test Plan

Member Completes Test Plan

Member Completes Test Report

Member Completes Test Report

Member Lists Product On-line (both QDL and EPL)

Member Marks Product with ID

Member Signs DoC And SDoC

Member Pays Listing Fee

Member Pays Listing Fee

Qualified and Listed
Qualification

Nordic will qualify and list:
- Device PHY
- µBlue controller and Host stack
- µBlue services running on nRF8200

Customer qualification needs:
- PHY – if you make your own
  - Not needed if you use modules
- Profiles – if changed/tuned compared to Nordic listings

Qualification specifications and cost structure are subject to change!
nRF8001

Nordic Semiconductor Bluetooth low energy family

μBlue

Single mode slave solution
**µBlue™**

A true coin cell *Bluetooth* low energy solution

- Single mode *Bluetooth®* low energy slave solution
- Fully integrated Phy, Link Controller and Host
- 13.5mA peak current
- Down to 17μA average current with 1s connection interval
- Complete solution with µBlue SDK
- 5x5mm QFN package

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**nRF8001**

<table>
<thead>
<tr>
<th>Prototype samples</th>
<th>Qualified samples</th>
<th>Mass production</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Selected customer)</td>
<td><em>(Bluetooth low energy v1.0)</em></td>
<td></td>
</tr>
</tbody>
</table>

- October 2009
- Q3 2010
- Q4 2010
Solution overview
nRF8001 + µBlue SDK = complete Bluetooth low energy solution

Flexible yet optimized
- Use the best-fit application MCU
- Easily expand with more profiles

Easy integration and qualification
- Separate MCU for application and link controller/host
- Prequalified PHY, LC and Host subsystem

µBlue SDK
- Includes qualified Bluetooth low energy profiles
- Portable C source code
**Key features**

**nRF8001 Block diagram**  
(Simplified)

- ACI
- Host FW
- Link Controller FW
- ROM
- Protocol MCU and Baseband logic
- Digital I/O
- DC/DC Reg.
- 2.4GHz Radio
- Oscillators
- Linear Reg.
- Application Controller
- LC network (opt.)

**Antenna and matching network**
- 16MHz crystal (req.)
- 32kHz crystal (opt.)

**Single mode slave solution**
- Fully embedded PHY, Link Controller and Host
- Serial interface to application controller

**Ultra low power operation**
- Sub 13.5mA peak current
- Sub 25µA average currents
- Coin cell battery operation

**Peripherals**
- Linear and DC/DC regulators
- 250ppm on-chip 32kHz RC oscillator
- ADC for battery level monitoring

**32-pin 5x5mm QFN package**
Optimized single mode slave implementation
Bluetooth low energy features

nRF8001 Bluetooth low energy stack

- Application Controller Interface (ACI)
- GATT
- SMP
- ATT
- L2CAP
- GAP
- Host Controller Interface (HCI)
- Link Layer (LL)
- Physical Layer (PHY)

Ultra low power PHY

Link Controller
- Standby, Advertising and slave role connected modes
- Encryption and authentication (Hardware accelerated AES-128)

Fully featured “Slave” Host
- Peripheral and broadcaster profile roles
- Fully featured SMP
- Attribute server and client roles

Application Controller Interface
- Chip and protocol stack Interface
- SPI based
### True ultra low power operation

<table>
<thead>
<tr>
<th>Peak currents</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Active (Linear regulator)</td>
<td>13.5mA</td>
</tr>
<tr>
<td>Active (DC/DC regulator 3V in)</td>
<td>11mA</td>
</tr>
<tr>
<td>Standby (32k XO)</td>
<td>3µA</td>
</tr>
<tr>
<td>Deep sleep</td>
<td>500nA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Connected mode average currents</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2s interval</td>
<td>10µA</td>
</tr>
<tr>
<td>1s interval</td>
<td>17µA</td>
</tr>
<tr>
<td>250ms interval</td>
<td>55µA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Advertising mode average currents</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2s interval</td>
<td>29µA</td>
</tr>
<tr>
<td>1s interval</td>
<td>56µA</td>
</tr>
<tr>
<td>250ms interval</td>
<td>110µA</td>
</tr>
</tbody>
</table>

### Coin cell battery operation
- 13.5mA peak w/ linear reg.
- 11mA peak w/ DC/DC reg. at 3V
- Headroom for application controller

### Years of battery lifetime
- Sub 25µA in connected mode
- 1 year++ on standard coin cell (220mAh)
nRF8002
Single chip system-on-chip solution for Proximity tags

Cost, size an power optimized
- Single chip solution
- Low cost BOM

Easy integration and qualification
- Configurable application
- Qualified Proximity / Battery profile system

Wide range of application peripherals to support:
- LEDs
- Buttons / Switches
- Buzzer
- Speaker
µBlue Prototype Kit