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# Optimieren von Bluetooth Low Energy Lösungen

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# Agenda

- Einleitung
- Simulation
- Echtzeitanalyse
- Systemtests

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# Zu meiner Person

**Adrian Eggenberger**
Software Architect

- 15 Jahre Embedded Software Entwicklung
- 3 Jahre BLE Erfahrung

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# BLE Referenzplattform

- Entstand auf der Basis von mehr als 15 Projekten
- Nordic nRF51 / nRF52 CPU
- Support von Peripheral, Broadcaster und Central Role
- Kooperatives Betriebssystem
- Optimiert auf minimalen Stromverbrauch
- Firmware-Update over the Air

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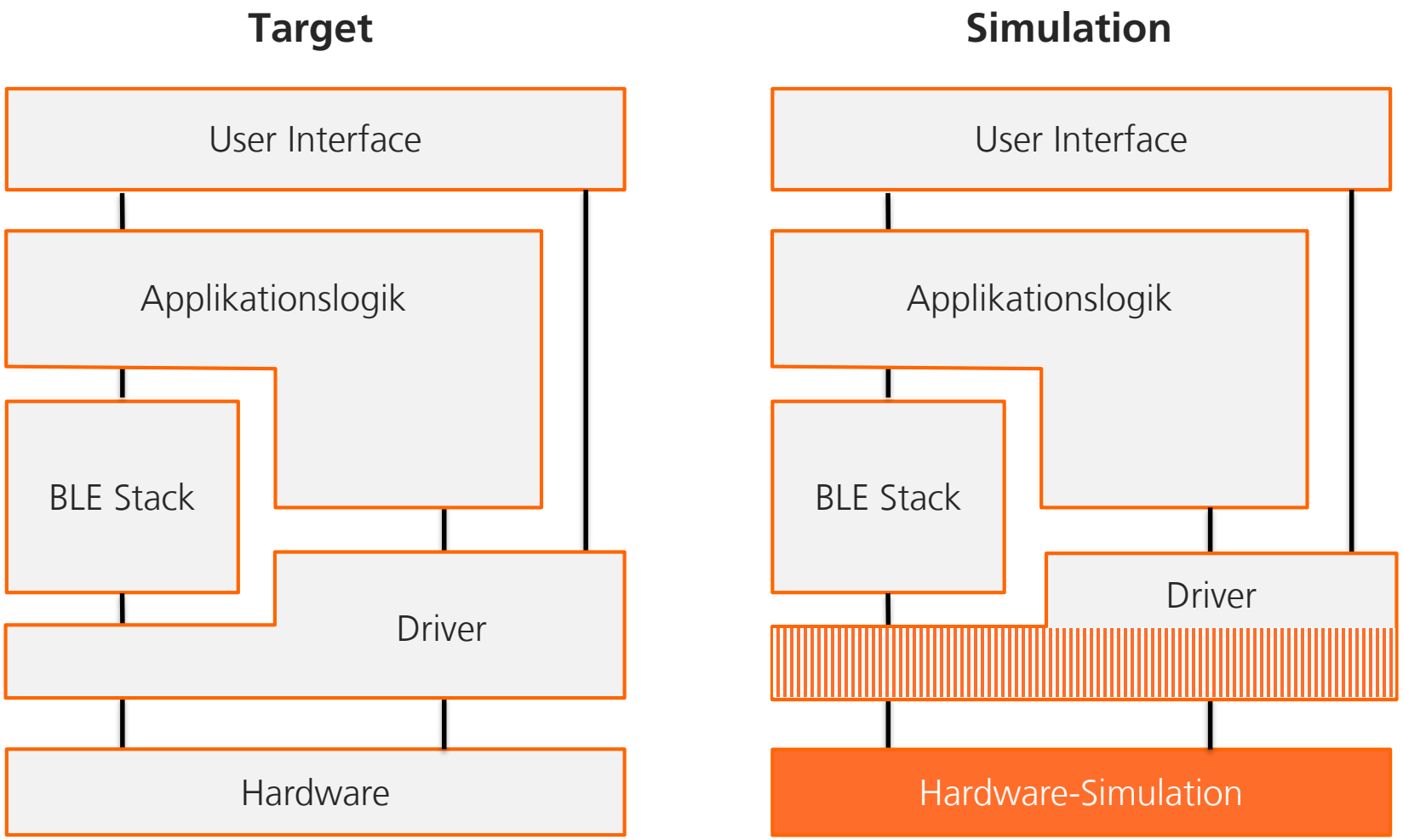
# Architektur



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# Vergleich

| | Target | Simulation |
|---|---|---|
| Entwicklungsumgebung | uVision, IAR, GCC | Visual Studio 2015 |
| Core | ARM, M16C, AVR, 8051, PIC, uvm. | X86, X64 |
| Hardware | Real | Simuliert |
| Programmiersprache | C / C++ | C / C++ / C# |

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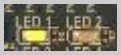
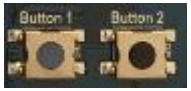
## Vorteile einer Simulation

- Entwickeln ohne Hardware
- Debugger
- Fehlersituationen und Extremzustände der Hardware
- Systeminformationen
- Entwicklungsgeschwindigkeit
- «Schönere» Architektur

## Nachteile einer Simulation

- Echtzeitverhalten

# Simulierte Hardware

| Peripherie | Simulation |
| --- | --- |
| LED |   |
| Button |   |
| Display / Touch |   |
| Flash / EEPROM |  flash.bin |

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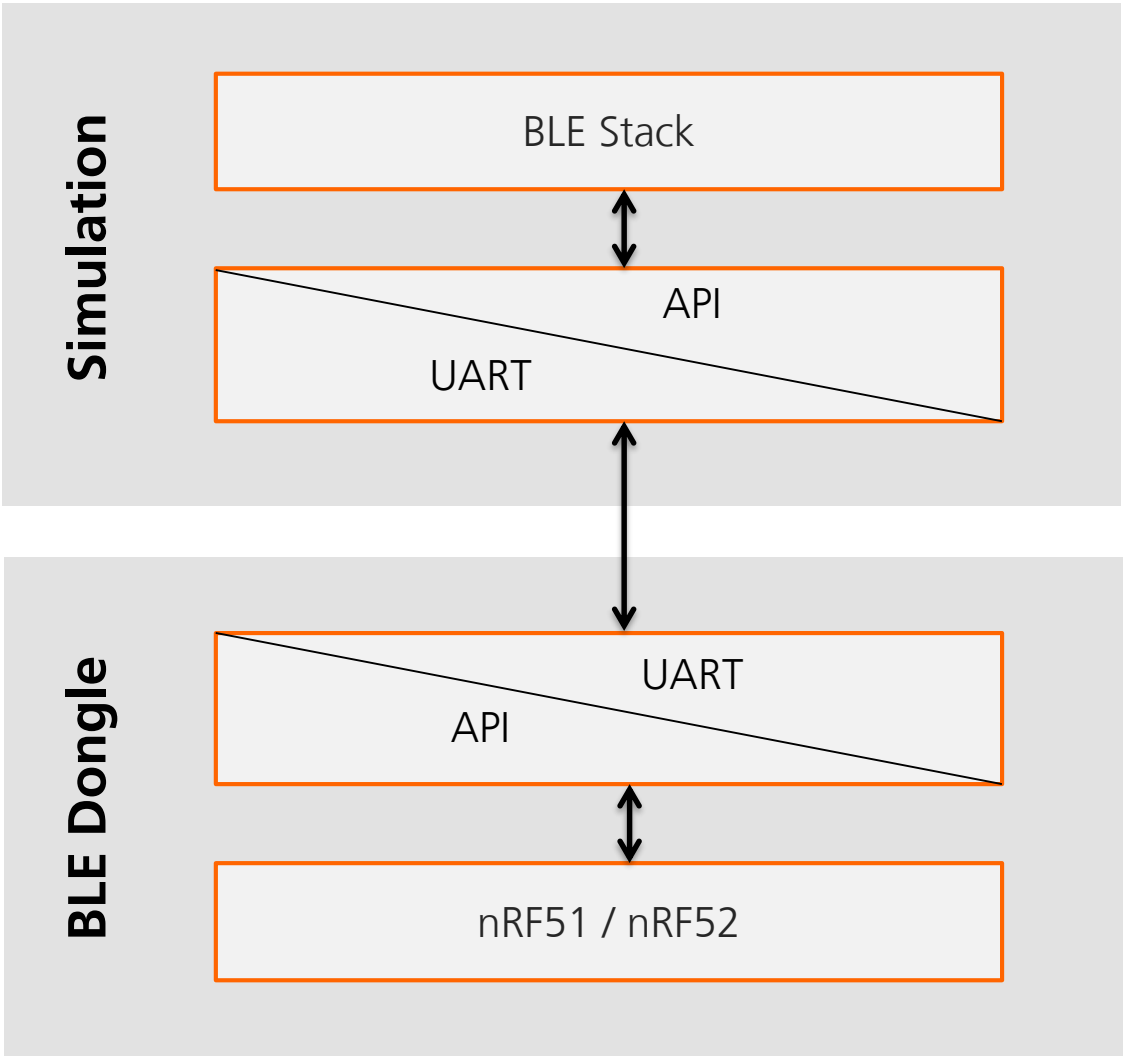
# BLE Connectivity

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# Demo


Arendi Simulation
Core
Reset
View Console
View Trace
Audio
Battery
2.90V
BLE
COM3
View Peripheral
View Central
Storage
BLE Peripheral
Advertising
Mode Normal
Interval 250.000ms
Timeout -
Connection
Peer Address -
Local Address -
Parameter -
Security -
Authentication -
BLE Central
Scan
Mode Disabled
Interval -
Window -
Timeout -
Connections
Peer Address -
Local Address -
Parameter -
Security -
Bluetooth SMART
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We are your solution.

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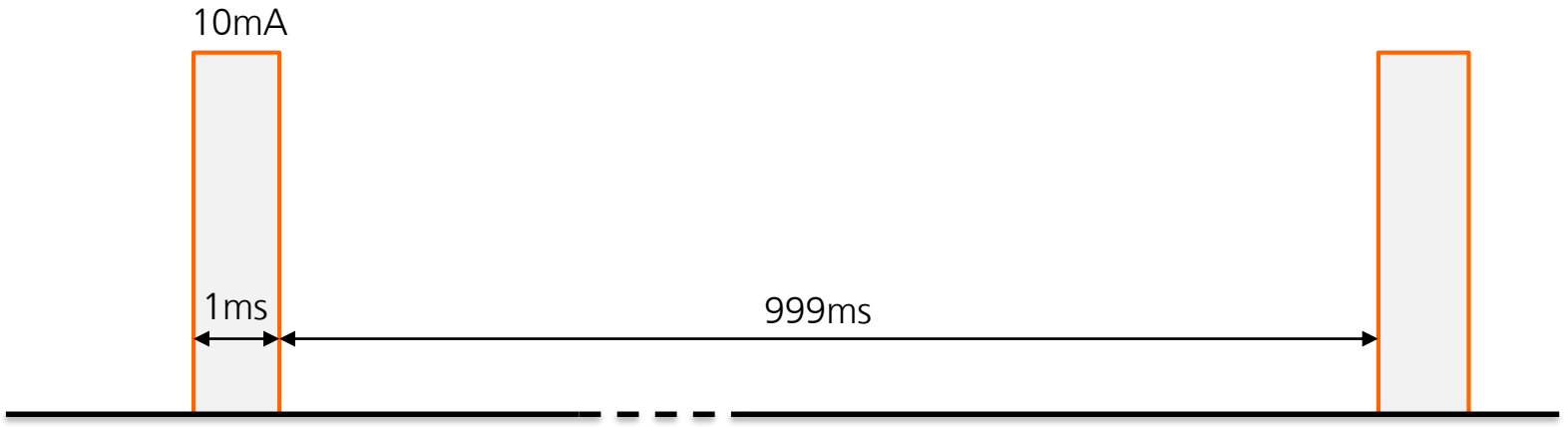
# Fragen in der Echtzeitanalyse

- Wie viele Aufrufe der Interrupt Service Routine Y?
- Was für Prozesse sind aktiv im System?
- Wie verhält sich das OS?
- Wie lange dauert Vorgang X?

# Optimiertes Echtzeitverhalten = Bessere Lebensdauer




Ø-Strom = ((10mA * 1ms) + (0mA * 999ms)) / 1000ms = 10uA

- 2.4 Jahre an einer CR2032 Knopfzelle
- Eine Verkürzung der zyklischen Rechendauer um 200us bedeutet bereits ½ Jahr mehr Batterielebensdauer.

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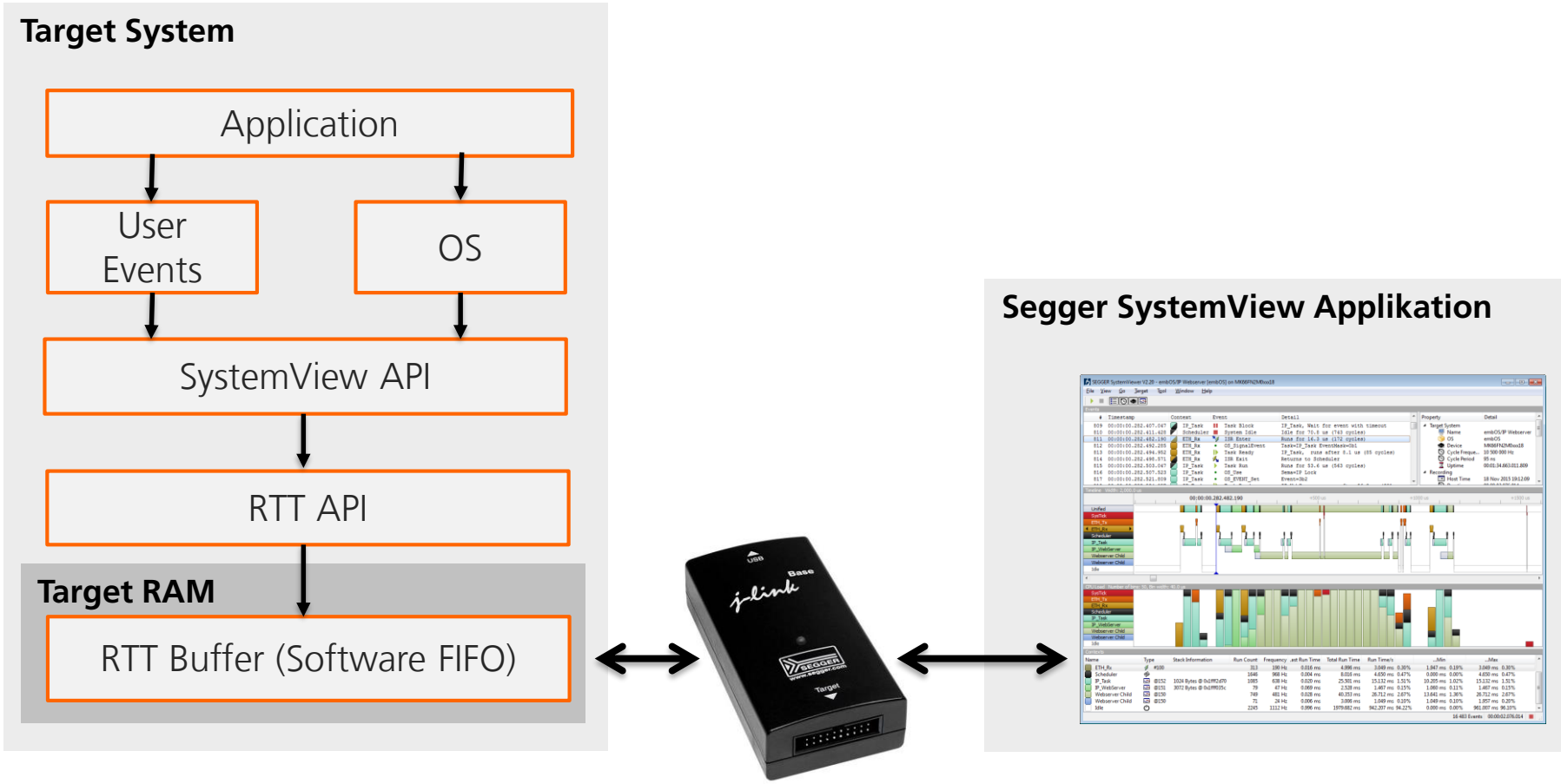
# Klassische Methoden

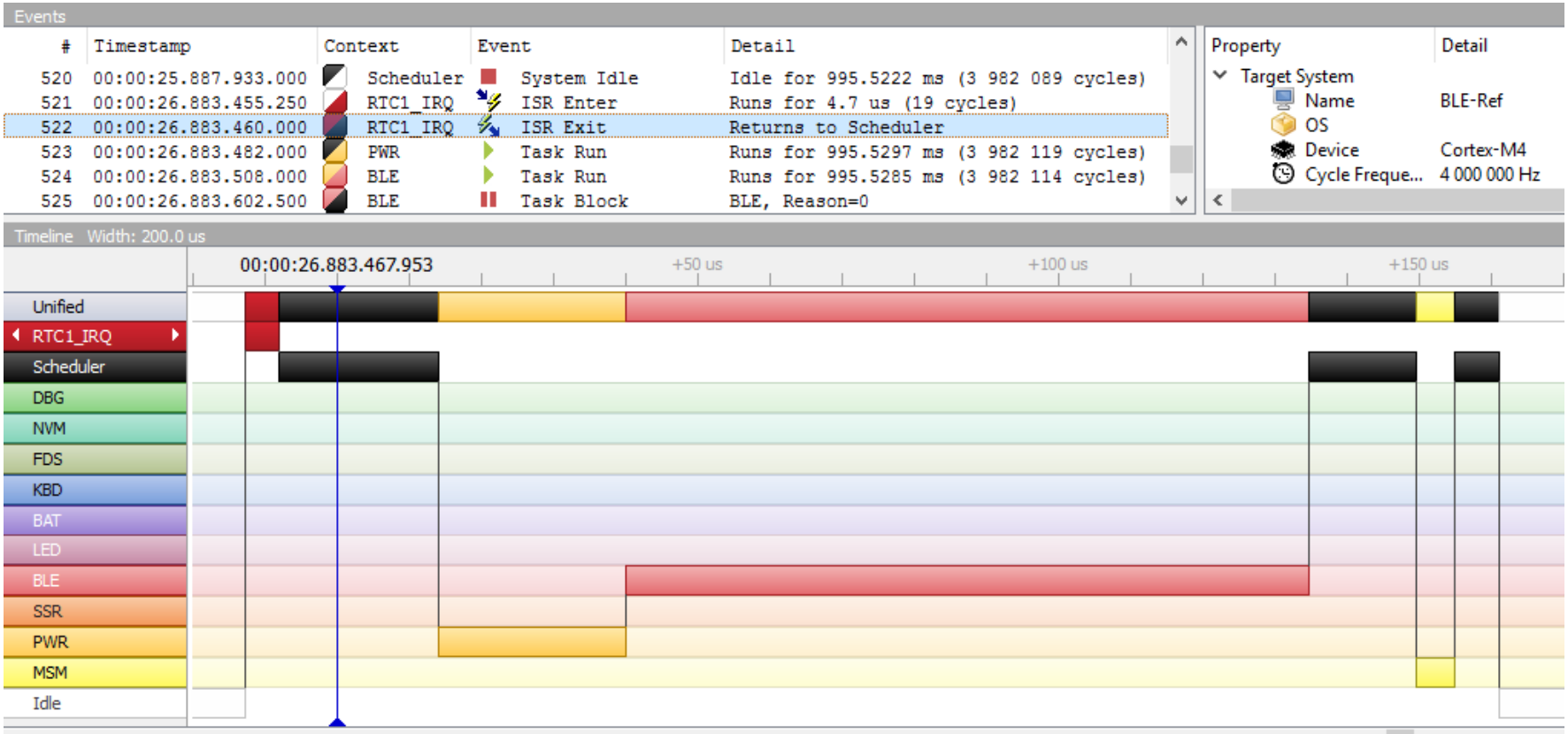
| Methode | Nachteile |
| --- | --- |
| Ausgaben auf Terminal | ▪ Starker Einfluss auf Timing<br>▪ Schnittstelle notwendig |
| Zeitmessungen über GPIO-Pin | ▪ Nur dedizierte Messungen<br>▪ Freie GPIO's nicht immer vorhanden |
| Breakpoints | ▪ Nur dedizierte Messungen<br>▪ In Kombination mit zeitkritischen Protokollen oft nicht anwendbar |

# Segger System View




Quelle: www.segger.com

# Demo


Events
# Timestamp Context Event Detail
520 00:00:25.887.933.000 Scheduler System Idle Idle for 995.5222 ms (3 982 089 cycles)
521 00:00:26.883.455.250 RTC1_IRQ ISR Enter Runs for 4.7 us (19 cycles)
522 00:00:26.883.460.000 RTC1_IRQ ISR Exit Returns to Scheduler
523 00:00:26.883.482.000 PWR Task Run Runs for 995.5297 ms (3 982 119 cycles)
524 00:00:26.883.508.000 BLE Task Run Runs for 995.5285 ms (3 982 114 cycles)
525 00:00:26.883.602.500 BLE Task Block BLE, Reason=0
Property Detail
Target System
Name BLE-Ref
OS
Device Cortex-M4
Cycle Freque... 4 000 000 Hz
Timeline Width: 200.0 us
00:00:26.883.467.953
+50 us
+100 us
+150 us
Unified
RTC1_IRQ
Scheduler
DBG
NVM
FDS
KBD
BAT
LED
BLE
SSR
PWR
MSM
Idle

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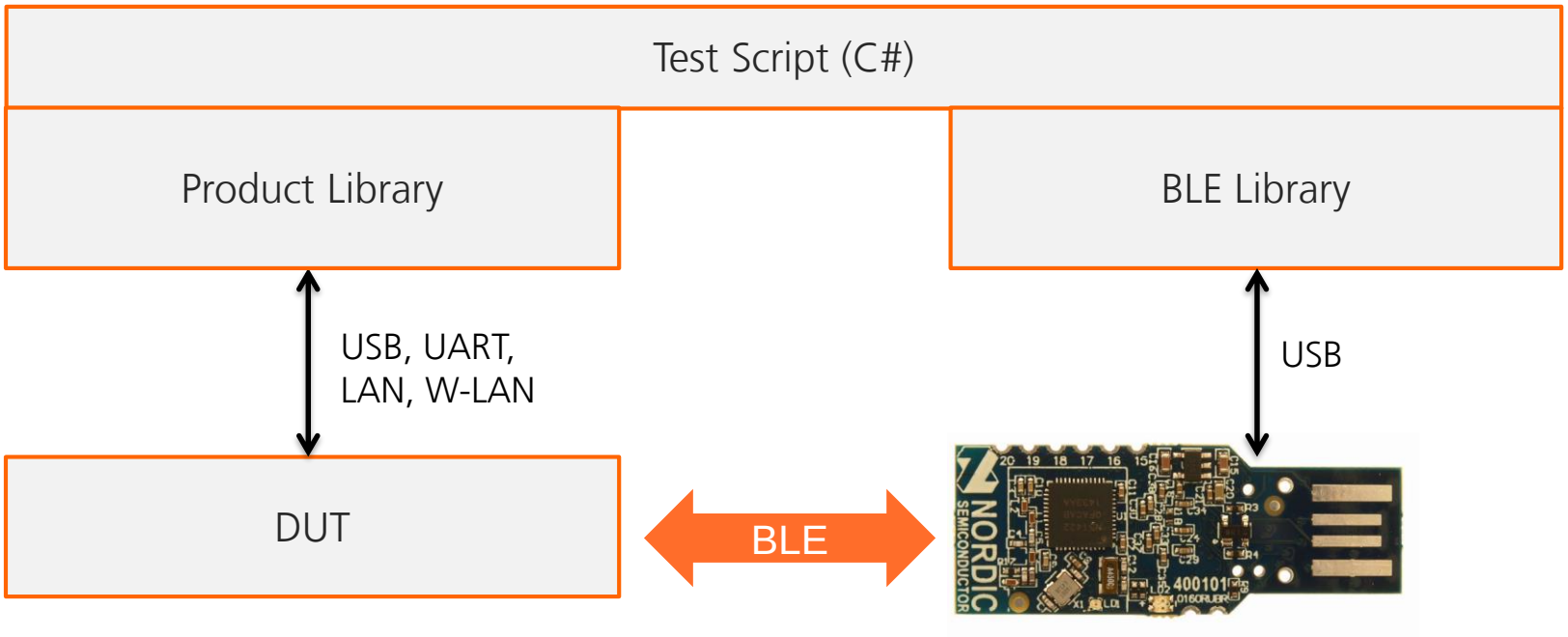
# BLE Systemtests mit NUnit



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# Demo

```
[Test, Description("Test BLE peripheral connection establishment and read battery level"), Repeat(100)]
0 references
public async void TestBleBatteryRead()
{
  // GAP address of the DUT
  BleGapAddress dutAddress = null;

  // search for the peripheral
  Search("0000AD00-0200-8F90-E411-7E83E0DE6066", out dutAddress);

  // connect the peripheral
  Connect(dutAddress);

  // discover services the peripheral
  await DiscoverServices();

  // read and check battery
  int battery = await ReadBattery();
  Assert.True(battery >= 0 && battery <= 100, "Battery value is out of range");

  // disconnect from DUT
  Disconnect();
}
```

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# Wir sind Ihre Lösung.

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