Paper reading 3

Tuesday, May 12, 2020 8:02 PM

BLE beacons for IoT applications: survey, challenges and opportunities

1. Focus of the paper: BLE beacons development for IoT applications
   - and beacons; applications and issues

   protocol design, characteristics of the Bluetooth signal, hardware components, casing designs, and software developments for realizing an interoperable, easy-to-deploy and scalable beacon-based IoT solution

   - BLE beacon applications (section 2)

   1) Indoor localization
      "BLE beacons' low production cost, ease of deployment, and easy accessibility to users" make it more suitable for indoor localization.
      Example: 19 beacons in an office area, and achieved <2.6 m error 95% of the time when one beacon was deployed every 30 m2, out-performing the <8.5 m error achieved by existing Wi-Fi networks.
   2) Proximity detection and interaction
      QR code needs to be installed and is not pleasing to generate, and NFC is only available within very short distance (10-20cm). BLE beacons can deal with these problems.
      Example: "AirDrop. When an iOS device is looking for other devices, it is basically scanning for iBeacon signals from other iPhones and MacBooks."
   3) Activity sensing
      For better knowing the user activity and micro-location.
      Example: "keep track of senior citizens' activity information" by wearing a "BLE beacon tag equipped with an accelerometer."
   4) Future applications
      BLE beacons on moving objects;
      BLE beacons accompanied by machine learning to better know the user activities and locations.

   - BLE protocols and RF signal characteristics (section 3)

   1) Bluetooth development
      At first, Bluetooth was considered most for reliability in providing hassle-free

communication between two devices. The emergence of IoT called for low power Bluetooth technologies.

2) BLE protocols

BLE devices are "connectionless and broadcast their signals periodically. " and "no device pairing is required to receive the signals advertised by the beacon".

Example: Apple's iBeacon is low power because of "the small data size of the advertising PDU".

Eddystone

3) Received signal strength (RSS) and distance

Received signal power: $P_r \propto (1/d^{\alpha})$

RSS = 10 log(P_r/1mW)]

RSS =$-\alpha$ log(d) +K

$-\alpha$ is the loss exponent, K is the offset constant, and d is the distance measured in meters

weaker transmit power reduces the range of signal coverage

signal fluctuation results in error in the theoretical distance estimation that is purely based on the RSS value

Ground truth is calculated by the equation.

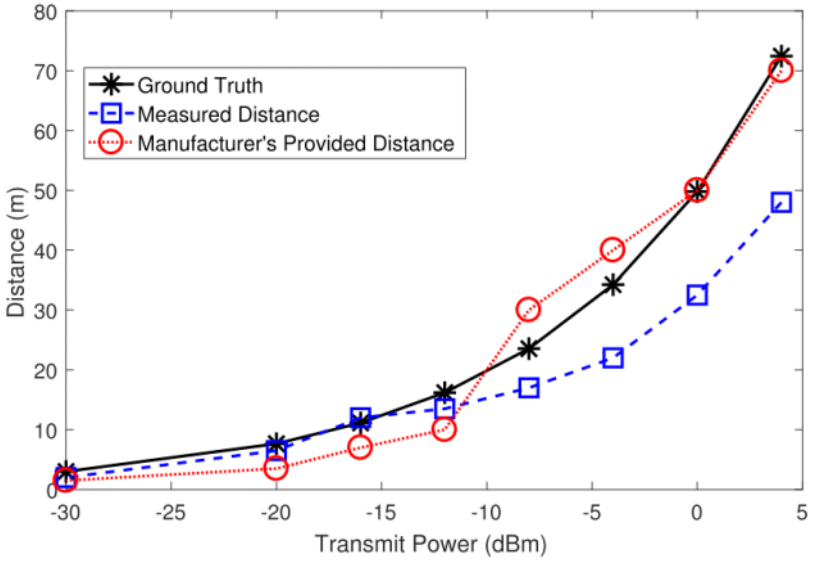
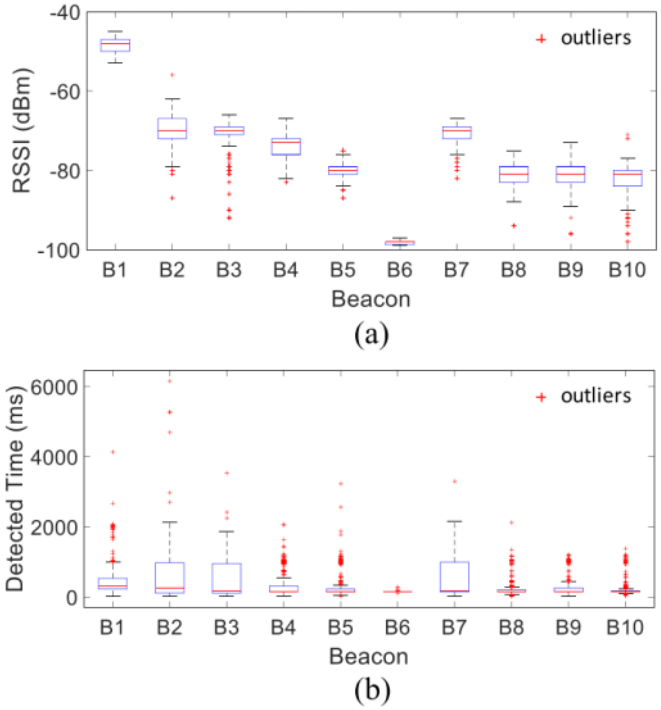


Fig. 3. Distance versus transmit power.

4) Beacon signals in dense environment

Due to the wide channel spacing (2 MHz), RSS detected varies across time even though each of the beacons is placed in a fixed location (i.e., the beacons are static during the time of experiment). Fig. 4(b) shows each of the beacons requires less than 1 s to be detected under good conditions.



- BLE beacon hardware (section 4)

1) Power consumption

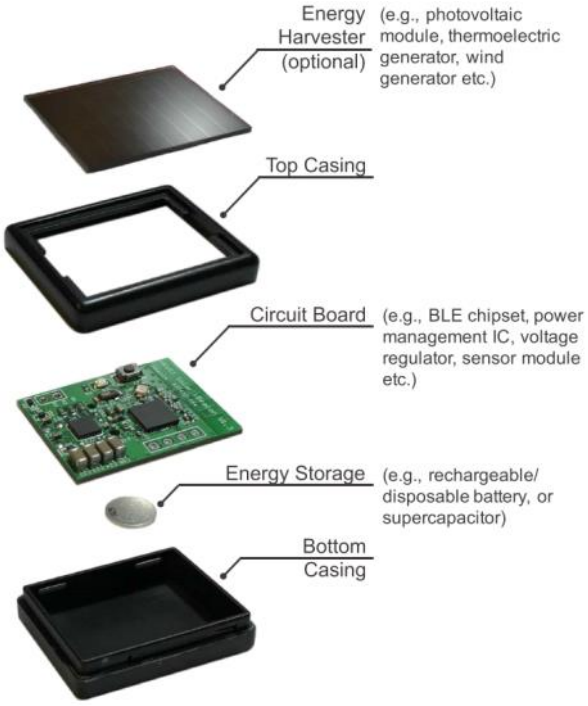


Fig. 5. Illustration of generic hardware components of BLE beacon.

Tp is the advertisement time, ti is the idle time between each advertisement, tT is the advertisement period. Initialization happens once during the system boot up.

$$I(t_T|t_p, I_p, I_i) = \frac{t_p I_p + t_i I_i}{t_T}$$

Average current draw during advertisement state can be used to estimate the power consumption, and thus guiding the design of the battery.

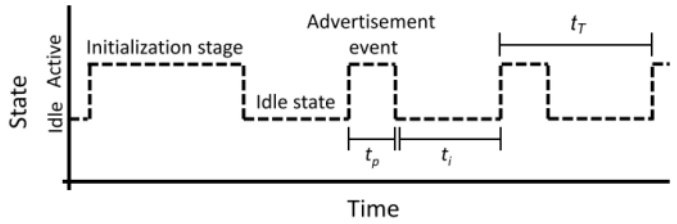


Fig. 6. Electrical characteristics of BLE beacon including initialization state.

2) BLE chipset

Current draw from the radio is most significant for BLE because there is little CPU computations done in the BLE chip. So, it is sufficient to analyze the current. 16KB RAM is enough for BLE, and larger ones do not aid the performance or development.

In the future, "external voltage regulator in their design to extend battery life and avoid complications."

TABLE III
COMPARISON OF REPRESENTATIVE BLE CHIPSETS
FROM LEADING MANUFACTURERS

BLE Chipset	Supported Version	Current
CC2541	Single Mode BLE v4.0	18.2 - 14.3 mA
nRF51822	Single Mode BLE v4.1	9.7 mA
PSoC 4 BLE	Single Mode BLE v4.1	15.6 mA

3)

- A survey of State-of-the-art research on BLE beacons
- Limitations of BLE beacons

1. Problems the paper wants to solve
   - Future research direction for BLE beacons
   - Challenges of BLE beacons
   - Opportunities for BLE beacons
2. Strategies used
   - Literature review

3. Unsolved problems, weakness, drawback

4. What interest me, what I learned