

NDN meets BLE: A Transparent Gateway for Opening NDN-over-BLE Networks to your Smartphone

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ABSTRACT

Bluetooth Low Energy (BLE) has seen a remarkable adoption and it is widely available on a variety of devices, such as modern PCs, smartphones, and battery driven sensors. A great number of software tools exist already that implement sensor-generic Bluetooth profiles. On the lower end, BLE features a robust energy efficient link layer. The technology, however, lacks multi-hop capabilities. In this demo we showcase a constrained NDN network that utilizes BLE L2CAP connections for robust communication. We enable multi-hop topologies and set up an NDN-to-BLE gateway in order to reuse existing BLE applications that expect GATT payloads.

CCS CONCEPTS

• **Networks** → **Network experimentation**; *Link-layer protocols*;

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1 INTRODUCTION

Information-centric networking (ICN) for IoT networks gained attraction due to its resilience mechanisms and performance benefits in wireless and lossy environments. In-network caching increases data availability, which is essential in many use-cases where data outage can harm business or even health. A reduced traffic flow in disrupted multi-hop environments that involves hop-wise (re-)transmission mitigates interference on the wireless medium and consequently increases data reliability while protecting energy resources of battery driven nodes. Furthermore, distributed caches and content-centric security simplifies multi-party data access from a cloud infrastructure or a local control application.

Potentials of BLE. We argue that ICN benefits from using Bluetooth Low Energy (BLE) mechanisms because of both technical as well as deployment reasons [3]. First, BLE offers a robust link layer

that uses time-scheduled frequency hopping, similar to TSCH, and is optimized for low power demands. This increases reliability on the lower layer and reduces battery consumption in low power and lossy environments. Second, BLE interfaces are widely available on many devices, in contrast to other constrained link layer technologies such as IEEE802.15.4. Hence, many devices with a common interface for humans, such as mobiles, may easily interact directly with IoT nodes, which are mostly prepared only for machine-to-machine communication. Third, a variety of ready-to-use Bluetooth applications exist to interface with virtually any sensor device, enabled by the Bluetooth Generic Attribute Profile (GATT). Those GATT profiles describe characteristics of sensors and are tailored to low volume sensor data. This enables out-of-the-box data visualization, logging, *etc.* At the negative side, plain BLE does not support multi-hop features and thus prevents many IoT deployments that need cover wide areas without deploying multiple gateways.

Current State of Art. Attam and Moiseenko [1] presented a proxy layer to run NDN over standard Bluetooth. They provided implementations for Linux and Android but did not focus on low power IoT networks. Zhang *et al.* [4] presented a framework that runs on low power IoT devices and implements features such as service discovery or link abstraction, which includes BLE. The implementation is still under construction and does not show details, *e.g.*, how ICN faces map to BLE connections. The Internet standard RFC 7668 [2] specifies an adaptation layer for IPv6 communication over BLE links. This enables multi-hop topologies for low power IP-networks.

Demo Overview. In this demo, we present an information-centric network that showcases two main features: (i) An NDN-over-BLE layer that allows to transmit NDN packets over BLE interfaces. This layer further enables multi-hop communication. (ii) An NDN-to-BLE gateway that transparently translates between NDN Interest/data packets and GATT profiles. This grants re-utilization of existing BLE applications.

2 CONTRIBUTIONS

NDN-over-BLE layer. One challenge that we need to tackle is the mapping of NDN to BLE primitives. To benefit from previous experiences, we adapt the concepts of IPv6-over-BLE [2]. A BLE node encapsulates NDN traffic into a custom connection-oriented L2CAP channel. Each connection is assigned its own *face*. In our custom connection management, every node switches between scanning and advertising periodically. Nodes connect to any other node that

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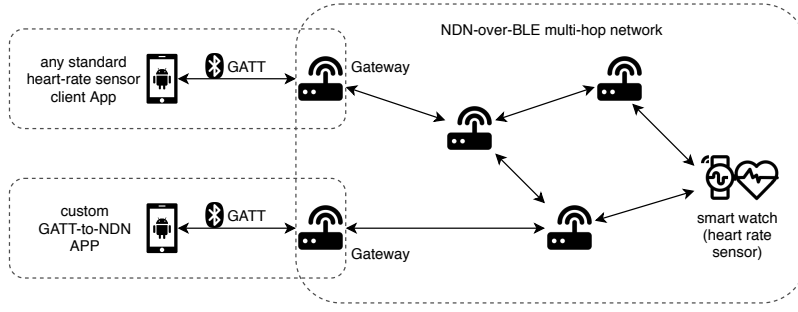


Figure 1: High-level architecture of the demo.

advertises a custom service UUID in the BLE advertisement string of type Incomplete List of 16-bit Service Class UUIDs.

NDN-to-BLE gateway. Our gateway primarily offers two different services: standard GATT services and advanced custom services. A (preselected) set of standard GATT services (e.g., heart rate sensor) allows to interact with any existing standard Android/iOS/Windows application. In addition to that, the gateway may also expose our own custom service to send NDN Interests for any user given name and receive the corresponding data chunks. This may be useful for debugging or maintenance.

When using the NDN-over-BLE software module, any node in the network is technically capable of being a GATT to NDN gateway. We explicitly allow the parallel deployment of multiple gateways to increase redundancy and load balancing. A single gateway may further be connected to multiple GATT clients at the same time.

Technically, the design of the gateway is based on the following functional principles: when a GATT client connects to the gateway, the client performs the common GATT service discovery and senses all exposed GATT services the gateway offers (e.g., battery, heart rate, custom NDN name service). When reading any service (or enabling notifications for any service), the GATT operation triggers the gateway to send an NDN Interest with a corresponding name. The data transferred through the NDN network is encoded using GATT compliant formatting defined by the corresponding GATT profiles. As soon as the requested content arrives at the gateway, the payload is forwarded to the connected GATT client. This allows the GATT client to receive the data from the NDN network transparently.

The high-level architecture of the presented setup is illustrated in Figure 1.

3 DEMO SETUP

The presented demo is deployed on a set of Nordic evaluation kits (*nRF52[840]dk*) as well as some inexpensive smart watches (*CK12*) as depicted in Figure 2. All nodes feature SoCs from Nordics nRF52 family of devices, which are based on a low-power ARM Cortex-M4 processor and provide an on-chip BLE radio. The smart watches additionally provide a heart rate sensor that is used as data source for this demo.

All nodes run the RIOT operating system, integrating CCN-lite as NDN network stack and NimBLE as BLE stack.



Figure 2: Hardware used in the setup.

For the multi-hop NDN network, we implemented an adaption layer that maps BLE L2CAP connections to faces in CCN-lite. This adaption layer also contains a custom BLE connection manager that uses the interfaces provided by NimBLE for scanning and opening new connections to relevant neighbors. To enforce a multi-hop topology on site, we make use of the link layer white list module provided by RIOT.

The gateway functionality is added through the custom implementation of the used GATT services for NimBLE, linking the GATT servers actions to CCN-lite API calls. On the client side, we use of-the-shelf Android phones with generic BLE sensor apps to read and visualize sensor data retrieved from the NDN network.

A Note on Reproducibility

We fully support reproducible research and perform all our experiments using open source software and an open access testbed. Code and documentation is available on Github at <https://github.com/5G-I3/ACM-ICN-2019-BLE-GATEWAY>.

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