Demo Abstract: Understanding Slotless Neighbor Discovery

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ABSTRACT

The process of two wireless devices meeting over-the-air for the first time is referred to as neighbor discovery. In mobile ad-hoc networks, battery powered devices duty-cycle their radios during neighbor discovery. As a result, they transmit and receive for very short durations of time and sleep at other times. Energy-efficient protocols, which guarantee short, bounded latencies while achieving low energy-consumptions are highly important for long battery lifetimes. In the past, neighbor discovery has been carried out mostly using slotted protocols, which subdivide time into multiple, equal length periods, called slots. An alternative are slotless protocols, which decouple beaconing from listening and can potentially achieve lower latency-duty-cycle-relations. As in slotted protocols, they also guarantee bounded latencies. However, understanding the mechanisms that ensure these deterministic bounds is more complex than for slotted protocols, since they rely on less intuitive concepts. In this demo, we propose a setup that visualizes the operation of two radios with slotless protocols in real-time, thereby providing insights that help in understanding slotless neighbor discovery. This demo is supposed to accompany the paper entitled "Griassdi: Mutually Assisted Slotless Neighbor Discovery Protocols", which appeared at IPSN 2017 as a regular paper.

CCS CONCEPTS

•Networks →Mobile networks; Mobile ad hoc networks; *Link-layer protocols;*

KEYWORDS

Neighbor Discovery, MANETs, Wireless Communication

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1 INTRODUCTION

In mobile ad-hoc-networks (MANETS), all network participants are typically powered by batteries. Before they can exchange data, they have to discover the devices in their surrounding and synchronize their clocks, which is a procedure called *neighbor discovery* (ND). To be energy efficient, all devices duty-cycle their radios. Thereby, each device only wakes up for short periods of time, during which it transmits packets or listens to the channel. ND between two devices A and B is complete, once device A sends a packet within a reception period of device B and vice-versa. Especially in applications in which ND is carried out continuously, such as contact tracing or location beaconing, the ND procedure contributes significantly to the total energy expenditure of the participating devices. Therefore, ND protocols that achieve short discovery-latencies with low duty-cycles (and hence energy-consumptions) are required. Most existing solutions realize neighbor discovery using slotted protocols, which subdivide time into multiple equal-length periods, called slots. There are active slots and sleep slots. At the beginning and the end of each active slot, a packet is sent. The device listens for incoming packets in between. ND schedules determine the pattern of active and sleep-slots. Multiple such schedules that guarantee bounded worst-case latencies have been proposed (e.g.,[1]). Whereas the slotted paradigm implies that transmission and reception are carried out jointly within each active slot, slotless protocols send beacons independently from their reception periods. In particular, as proposed in [5], a device periodically transmits a beacon with a period of T_a time-units. Reception is carried out continuously for d_s time-units with a period of T_s time-units. Such slotless, periodic-interval (PI)-based protocols have been adopted by Bluetooth Low Energy and ANT/ANT+. Further, optimized, PI-based protocols have been proposed [3], which potentially achieve lower latency-duty-cycle-relations than all known discovery protocols, including slotted ones. These protocols achieve bounded latencies by choosing the interval lengths (T_a, T_s, d_s) according to a mathematical framework. Unlike in slotted protocols, the mechanisms for achieving deterministic bounds are not intuitive.

Demo Setup: The main part of our proposed demo is a *neighbor discovery panel*, which allows for manually controlling two radios. Using a dial, one can directly choose the duty-cycle of two radios. One can start the operation of these radios by two buttons. By observing the current consumptions of the devices, one can trace the packets sent and the reception windows in real-time. Thereby, one can see the main mechanism for bounding the latency: The time distance between neighboring advertising packets and scan-windows decreases continuously over time until they overlap. In addition, the amount of time this distance is decreased in every step is constant [2].

2 ANALYZING SLOTLESS ND

Unlike the popular belief, except for a finite number of singularities, slotless PI-based protocols achieve deterministic upper latency bounds for all parametrizations. It can be proven that, for a certain combination of multiples $(n, m) \in \mathbb{Z}$ of T_a and T_s, the temporal distance between an instance k of the scan window and its closest neighboring advertising packet shrinks by a constant value γ [2]. Further, there is a pair of (n, m), for which $\gamma < d_s$. If the distance shrinks in steps $< d_s$, a scan window is reached deterministically within a limited number of steps. The parameter γ is determined solely by T_a and T_s. Since mutual discovery is only complete after two devices have received a packet from each other, *mutual assistance*, a technique to decrease the mean latency without increasing the worst-case latency has been proposed in [3]. Each beacon contains a temporal hint on the next scan window of a device. Once such a beacon is received, the remote device sends an additional packet within the next listening period of its opposite device. In addition to mutual assistance, the mechanism for achieving bounded latencies can be studied with our proposed demo, as described next.

3 PROPOSED DEMO

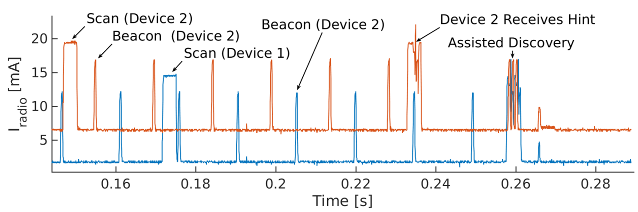

Figure 1: Current snapshot of the protocol [3].

The mathematics behind the computation of n, m and γ is non-intuitive. However, as already mentioned, the temporal distances between a scan-window and its neighboring advertising packets is reduced continuously until a match occurs. This can be observed in real-time, if the operation of the radio could be visualized. In our proposed demo, we display the current consumption of two radios during a ND procedure. A snapshot of this is shown in Figure 1. The short spikes depict the advertising packets of each device, whereas the broader ones depict the scan windows. The scan windows are always centered, such that the temporal distance to its neighboring advertising packets become visible. From the snapshot, one can also observe mutual assistance. However, unlike in the live demo, such a snapshot cannot depict the shrinkage or growth of the temporal distance. In our proposed demo, the packets and scan windows are displayed in real-time using a digital oscilloscope displaying the current consumption. One can easily configure and control the system. We have implemented the PI-kM-A2W-Protocol [3] on two nodes mounted on a setup called *neighbor discovery panel*, which is depicted in Figure 2. Based on a modified open-source BLE stack [4], the nodes implement a version of the protocol that can be parametrized and communicates results via an UART interface. The selected duty-cycle, the discovery latencies and other information are shown on a laptop screen. The offset between beaconing and scanning on each node is determined randomly whenever the button is pressed.

The duty-cycle of two nodes can be chosen between 0.1 % and 5 % using the dial in the middle of the lower part of the panel. Further, each node can be started using a button. Once this button for a node is pressed, it starts running the neighbor discovery protocol and the beaconing and listening phases can be observed on the oscilloscope. The user determines a random time offset between the two nodes by pressing the buttons accordingly. Once mutual discovery has been achieved, the nodes stop operating and the buttons shine brightly to indicate successful mutual discovery.

Figure 2: Proposed neighbor discovery panel.

Using this demo, one would be able to study the impact of different protocol parameters on the neighbor discovery latency. At the same time, the discovery procedure may be visualized in real-time, leading to be a better understanding of the protocol. This demo could also be adapted to other protocols, like the slotted ones, which albeit are simpler to understand.

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