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Latency Evaluation of an IoT Bluetooth 5 Opportunistic Edge Computing System

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Abstract

There are more and more IoT devices that need to be interconnected with each other to perform compute-intensive tasks due to their limitations in terms of storage, computing power and energy consumption. However, IoT devices encounter the problem of the lack of wireless connectivity in places where they are deployed or where they are traveling through. A solution to this problem consists in the use of opportunistic systems, which provide connectivity and processing resources efficiently by reducing remote communications to the cloud. Opportunistic networks are considered useful both in IoT scenarios where the cloud becomes saturated (e.g., due to an excessive amount of concurrent communications or to Denial-of-Service (DoS) attacks), as well as in those areas where wireless communications coverage is not available, such as it frequently occurs in rural areas or during natural disasters, wars or when other factors cause network outages. This paper presents the design of a novel opportunistic Edge Computing system based on the use of Bluetooth 5 and Single Board Computers (SBCs). To illustrate the performance and feasibility of the proposed system, latency tests are presented. For such latency tests, an experimental testbed was built by communicating two separate IoT networks (each network consisted of an IoT node and an opportunistic Edge Computing gateway). The tests calculated the time of message propagation from one end node to another. The obtained results show that the developed system obtains latencies between 850 and 1200 ms, depending on the scenario, which make the solution viable for many application scenarios with low latency requirements.

1 Introduction

Some reports estimate that 75.000 million Internet of Things (IoT) devices will be in operation by 2025 [1]. Many of such IoT devices are limited in terms of storage, computing power and

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power consumption, so they must rely on other remote devices to perform compute-intensive tasks. Moreover, smart IoT devices can be anywhere and will need to be interconnected, but in some areas, there is not always wireless communications coverage. In order to solve this problem, opportunistic communication systems can be useful, since they facilitate the collaboration among IoT devices to share resources and services when they are available [2]. This paper presents an IoT architecture that makes use of the OEC paradigm and proposes and evaluates the latency of a Bluetooth 5 based system capable of freeing IoT systems from the need for an Internet connection.

2 Design and Implementation

The proposed OEC IoT architecture is shown in Figure 1, which consists of three layers:

- IoT device layer. In this layer, there are different IoT networks (A and B in Figure 1) whose devices are capable of exchanging data with the upper layer. Such data can be sent to the upper layer, which provides multiple services.
- OEC Smart Gateway layer. This layer consists of gateways with the ability to provide services opportunistically with reduced latency (due to their proximity to the IoT nodes). The data from the IoT devices are stored in a Distributed Hash Table (DHT) network shared by the gateways.
- Cloud layer. This layer is responsible for providing services that cannot be provided by the OEC smart gateways, like compute-intensive processing or the storage of large amounts of data.

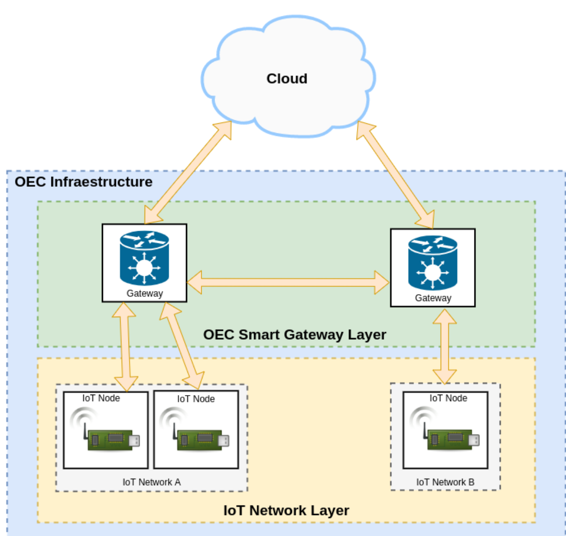

Figure 1: Designed OEC communications architecture.

For this paper, the implementation of the proposed communications architecture relies on Bluetooth 5 for the communications between the OEC IoT nodes and the smart gateways.

The rest of the architecture can make use of WiFi/4G networks. Furthermore, the cloud layer provides a routing service for communicating the different networks whose gateways are not directly connected.

3 Results

A testbed was built to carry out the experiments presented in this paper: it is composed of two IoT nodes (nodeA and nodeB) based on two SBCs (Raspberry Pi 3B) that have a Bluetooth mesh interface (Nordic nRF52840 development kit) connected to the serial port. Two gateways (GwA and GwB) based on Raspberry Pis are used: a Raspberry Pi 3B+ and a Raspberry Pi Zero. Two Nordic nRF52840 development kits provide Bluetooth mesh communications to the Raspberry Pis. Such Bluetooth mesh interfaces are provisioned on the same network for the nodes and the gateways to allow for their communication. Two scenarios were compared in the tests. The first scenario (called "Cloud") consists of two IoT networks: one with NodeA and GwA and another one with nodeB and GwB. The second scenario (called "Edge") is composed of two nodes (NodeA and NodeB) and a gateway (GwA).

With the described testbed, latency has been measured by considering the time it takes to send a typical IoT message (for these experiments, an 11-byte packet) from the nodeA to nodeB. In both compared scenarios, the packet is sent to an intermediate gateway by using Bluetooth 5 mesh with a TX power of 0 dBm. The gateway receives the packet through its serial port and then uploads the message payload to the shared DHT network. In the case of nodes of different opportunistic networks, the receiving gateway collects the packet from the sending gateway and sends it to the local IoT node through Bluetooth 5.

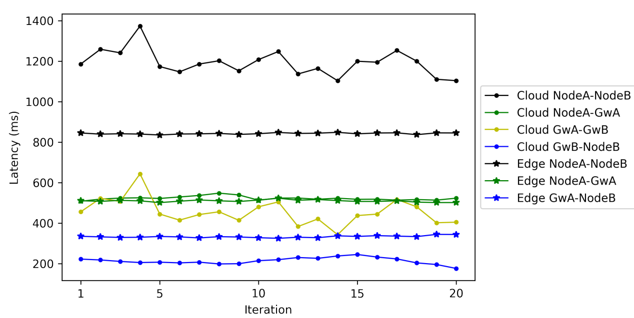

Figure 2: Latency of the different node and gateway communications.

The obtained latency times are shown in Figure 2. Such results indicate that the minimum time to send a packet is slightly more than 800 ms if both nodes are in the same network ("Edge NodeA-NodeB" line in Figure 2), but if they are in different networks, the time increases to roughly 1,200 ms ("Cloud NodeA-NodeB" line). This time difference is related to the propagation of the DHT network messages from one gateway to another. It can be also observed in Figure 2 that the communications latency between nodes and gateways (i.e., "Cloud/Edge NodeA-GwA") is the one that influences the most the latency of the system, so its minimization should be further analyzed to be optimized.

4 Conclusions

This paper presented the initial design and latency evaluation of a Bluetooth 5 based OEC IoT system. The obtained results show that the developed system, in the tested scenarios, provides relatively low latency values (between 850 and 1,200 ms) depending on whether the nodes are in different networks or not. These first results indicate that the proposed opportunistic network is a viable solution for many scenarios with low latency requirements. Nonetheless, future work will be dedicated to optimizing the OEC IoT system to reduce the overall latency.

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