Intelligent Device-to-Device Communication in the Internet of Things

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***Abstract*—Analogous to the way humans use the Internet, devices will be the main users in the Internet of Things (IoT) ecosystem. Therefore, device-to-device (D2D) communication is expected to be an intrinsic part of the IoT. Devices will communicate with each other autonomously without any centralized control and collaborate to gather, share, and forward information in a multihop manner. The ability to gather relevant information in real time is key to leveraging the value of the IoT as such information will be transformed into intelligence, which will facilitate the creation of an intelligent environment. Ultimately, the quality of the information gathered depends on how smart the devices are. In addition, these communicating devices will operate with different networking standards, may experience intermittent connectivity with each other, and many of them will be resource constrained. These characteristics open up several networking challenges that traditional routing protocols cannot solve. Consequently, devices will require intelligent routing protocols in order to achieve intelligent D2D communication. We present an overview of how intelligent D2D communication can be achieved in the IoT ecosystem. In particular, we focus on how state-of-the-art routing algorithms can achieve intelligent D2D communication in the IoT.**

***Index Terms*—Device, intelligent communication, Internet of Things (IoT), routing.**

I. Introduction

WITH the advent of the Internet, people have become increasingly interconnected at an unprecedented scale [1]. However, due to the proliferation of short-range networks and the prevalence of devices connected to these networks, a seamless interconnection between devices is gradually being created. Such short-range networks include wireless sensor networks (WSNs), wireless fidelity (WiFi), Bluetooth, radio-frequency identification (RFlD) networks, and ZigBee. It is envisaged that devices will be connected together to create, gather, and share information. The process of sharing, gathering, and creating information will involve a series of communication between devices with or without human intervention. These devices are various types of objects/things with embedded intelligence and communication capabilities. Examples of such devices are sensors, smartphones, cars, home appliances, health care gadgets, or RFID tags. Therefore, not only humans are being interconnected, but devices also are being interconnected. This paradigm shift has led to the concept of the Internet of Things (IoT). The IoT is a radical evolution of the current Internet, which has been transformed from providing human interconnection into a network of interconnected devices. These devices interact with the physical world using Internet protocols and standards in order to collect data from the environment [1]. The IoT will enable the transformation of sensed or gathered data into intelligent information, thus embedding intelligence into our environment. In addition, the IoT will involve billions of devices that have the ability to report their location, identity, and history over wireless connections [2].

The realization of the IoT is gradually coming into fruition as a result of several major trends. Advancements in the field of digital electronics have immensely contributed to the development of miniature devices that can sense, compute, and wirelessly communicate within short distances. These devices exist as part of our everyday lives in areas such as health care, smart grid, home appliances, retail, etc. In addition, the decreasing costs of these devices have also led to a drastic increase in their deployments in recent years.

According to [3], in 2003, when there were about 6.3 billion people in the world, only 500 million devices were connected to the Internet. Thus, at that time, there was less than one device per person. As a result, the IoT did not yet exist in 2003 since the number of connected devices was relatively low. Subsequent to 2003, after the unveiling of the first set of smartphones and tablet personal computers by manufacturers, there was a gradual increase in the number of connected devices. By 2010, the number of devices connected to the Internet rose to 12.5 billion while the world's population increased to 6.8 billion, making the number of connected devices per person more than one for the first time in history [3]. From a recent forecast outlined in [4], the number of connected devices will double compared with the number of humans on earth by 20l3 and will grow to an estimated 25 billion connected devices by 2015, when the world's population is expected to be about 7.2 billion. Moreover, it has been predicted that almost 50 billion devices will be connected by 2020 [5], [6]. The number of devices will rise to over four times as high as the global population. This increase will be accelerated in part by the enhanced capabilities of devices used every day to orchestrate and manage human activities [7].

Some of the technologies that have paved the way for the possibility of interconnectivity of everyday devices have