Chapter 46
Cellular IoT for Mobile Autonomous Reporting in the Smart Grid

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ABSTRACT

Wireless access technologies are being embedded in utility meters, health devices, public safety systems, among others. These devices have low processing power and communicate at low data rates. New communication standards are being developed to support these machine-type communications (MTC), such as Cellular Internet of Things (CIoT), which is being developed by the third generation partnership project (3GPP). CIoT introduces cooperative ultra-narrow band (C-UNB) communications. It supports ad-hoc uplink transmissions, delay-tolerant downlink transmissions, and a simple authentication scheme. The C-UNB approach is proposed for Mobile Autonomous Reporting (MAR) applications, but it is not clear if it can be used for smart grid systems, such as sensors and smart meters in the Advanced Metering Infrastructure (AMI). In this paper, the authors review the C-UNB approach, study its performance in terms of collision rate and throughput, and discuss its potential for smart grid reporting applications.

1. INTRODUCTION

Industries in the energy, environmental, logistics, and surveillance fields have widely employed remote monitoring. Remote monitoring can be associated with Internet of Things (IoT) when the measurements are transmitted over Internet Protocol (IP) networks or the public Internet. A variety of short-range wireless links and/or public mobile networks can be used to connect sensors to data collection servers (Ahmed et al., 2013).

Current smart grid systems and test-beds such as the ones described by Hahn (2013) use data communications and IP networks to facilitate the remote monitoring, analysis, and control of the power grid,

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with the goal of improving its efficiency and reliability. For instance, as described in Hertzog (2011), "the typical mid-sized utility in the USA has between 2000 to 5000 devices online to provide Supervisory Control and Data Acquisition SCADA communications, condition-based monitoring, and polling for event-specific data in their substations."

Devices such as smart meters are part of the Distribution/Customer domain. They are connected to the smart grid either by direct connections to the data collection center, or through one or more concentrators or relay agents. In the latter approach, each neighborhood may have one or more concentrators, as shown in Figure 1. Smart meters can be connected to the concentrator using proprietary wireless mesh technologies or access protocols such as IEEE 802.15.4g and 6LoWPAN. It forms a neighborhood area network (NAN). In the research by Berthier et al. (2014), a NAN consisting of 30,000 smart meters and 90 concentrators was studied using real-world packet traces. While the smart meters-to-concentrator links used proprietary communication protocols, the concentrator relays the information to the data collection server using public mobile networks (i.e., cellular links).

On the other hand, the direct connections approach uses public mobile networks to connect smart meters directly to the data collection server, as shown in Figure 2. An overview of machine-type-communications or machine-to-machine (M2M) in public mobile networks is described by Norp & Landais (2012). It lists the main requirements to trigger a connection, for instance, from a collection service located in another network trying to reach a device inside the mobile network. Essential requirements are the identity of the device and the application, a sequence number that can be used to detect duplicate packets and send acknowledgments, and other optional requirements. In particular, Cellular IoT (CIoT) offers new possibilities to connect thousands of IoT devices such as sensors and smart meters using cellular networks. The third generation partnership project (3GPP) technical report TR45.820 (2015) proposes new physical and data link layer protocols for CIoT called clean-state radio access technologies. These solutions are being designed for devices that periodically send reports to a data collection agent or management facility. The goals of clean-slate radio are to support low-bandwidth (less than 45 kbps), low-cost devices (less than five dollars), long-battery life (at least 10 years), and extended coverage (i.e., to support larger cells and indoor devices).

Among the different clean-state radio access technologies being defined in the 3GPP technical report, the Cooperative Ultra Narrow Band (C-UNB) proposes a novel way to support "massive asynchronous access of small packet transmissions", which is a term defined by Nielsen et al. (2015). They discussed the need for a simplified access control scheme for the next generation of smart meters. The traditional access control of 3GPP LTE systems is based on the idea that the network has a number of designated channels for uplink transmissions, and when a device enters the network or needs to allocate a new channel for transmission, it needs to request access using a Physical Random Access Channel (PRACH). For traditional applications that use transmission control protocol (TCP), Huang et al. (2013) did a performance study of LTE networks. However, for M2M communications in LTE networks, there are many devices that may transmit simultaneously and this may result in congestion due to insufficient capacity, as shown by Andreev et al. (2015). Osti et al. (2014) evaluated the random access procedure of the downlink control channel in LTE networks for M2M communications using a parallel Slotted Aloha model and they showed that the LTE signaling is a bottleneck for a very large number of devices. However, they did not take into account fading and propagation issues in their analysis.

In the C-UNB access control scheme the device does not need to request access using PRACH. It selects a random uplink channel and transmits directly. C-UNB has an intermediate server inside the mobile core network, which acts as a concentrator or relay agent. The C-UNB server receives data from