Evaluation Form – Technical Background Review

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_______ / 30 Technical Content

- Current state-of-the-art and commercial products
- Underlying technology
- Implementation of the technology
- Overall quality of the technical summary

_______ / 30 Use of Technical Reference Sources

- Appropriate number of sources (at least six)
- Sufficient number of source types (at least four)
- Quality of the sources
- Appropriate citations in body of text
- Reference list in proper format

_______ / 40 Effectiveness of Writing, Organization, and Development of Content

- Introductory paragraph
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Low Power Wide-Area Network Development Kits

Introduction

Being able to monitor mobile sensors is critical to the expanding internet of things. When ethernet cable, WiFi, or other local area coverage is unavailable, low power wide-area networks (LPWAN) can provide internet connectivity for low power and low-bandwidth applications. This paper is a review of the commercially available applications, underlying technologies, and methods of implementation for a device on an LPWAN network.

Commercial Applications of LPWAN Development Kits

LPWAN development kits are used for prototyping IoT solutions on one or more wide-area networks. A development kit's rudimentary features are a microcontroller, radio module, USB power source, and 5-20 GPIOs. Commercial products with only the essentials cost in the \$40-\$60 price range [1]. An intermediate-level kit includes dedicated antennas, expanded connectivity to multiple networks, and battery power capability. The Arduino MKR NB 1500 is a development board that connects an Arduino project to the LTE-M or NB-IoT network. The board includes a dedicated LTE antenna but requires an additional SIM card to connect to the network. The Arduino MKR NB costs \$77.00 [2].

Advanced development kits are in the \$100-150 dollar range and contain SIM cards and GPS support. The Nordic Semiconductor nRF9160 DK can be used for LTE-M, NB-IoT, or GPS communication. The nRF9160DK costs \$139.00 (almost twice as much as the MKR NB), but it includes a GPS antenna and a bundled iBasis SIM card preloaded with 10 MB [3]. Poem Technology's DASH CAT-M1 Module is an IoT development platform that is notable for its modularity. The DASH contains a Hologram SIM card with flexible pay-as-you-go data plans to connect to the LTE-M and NB-IoT networks. An array of 25 general-purpose input-output pins (GPIOs) enables connection to sensors and peripherals. The DASH's two on-board microcontrollers implement user and system functions separately. The system microcontroller is responsible for managing the radio module and connections into the Hologram's cloud service. The user microcontroller exclusively hosts the user's programs and is fully compatible with Arduino APIs [4]. The Poem DASH development kit costs \$114.95 [5].

Underlying Technologies of LPWAN Development Kits

Wireless Networks

There are two complementary LPWAN network technologies underneath IoT devices: LTE-M and NB-IoT. Both LTE-M and NB-IoT use the existing wide-area LTE network infrastructure. NB-IoT is superior in terms of coverage and connection count. Connection count is a crucial metric for large-scale IoT applications. NB-IoT has been shown to support an average of 50,000 connections per cell. LTE-M has not been optimized to support large-scale applications, and more testing would be needed to determine its average connection count. Nonetheless, LTE-M is better suited for applications that involve human interactions. LTE-M has a higher throughput and a wider carrier bandwidth than NB-IoT. Furthermore, LTE-M is capable of transmitting voice signals, while NB-IoT is not. NB-IoT has a 200 KHz carrier bandwidth, a 66.7 Kbps peak uplink throughput, and a 32.4 Kbps peak downlink throughput. The LTE-M network has a 1.4 MHz carrier bandwidth, 200 Kbps peak uplink throughput, and a 750 Kbps peak downlink throughput [6]. Overall, LTE-M is the preferred networking technology for high-bandwidth human-centered applications like health care monitoring.

Power Saving Techniques

The principal component of an IoT development kit is the radio module. The radio module is responsible for transmitting and receiving RF signals in the desired carrier frequency ranges. The development kit in [2] uses a u-blox SARA-R410M-02B radio module. The SARA provides software-based multi-band configuration enabling LTE-M and NB-IoT coverage internationally. It is recommended for devices that require long battery lifetimes, such as smart metering, smart asset tracking, and alarm panels [7]. Radio modules use two main techniques to minimize power consumption.

Extended discontinuous reception (eDRX) is one method that LTE-M radio modules use to conserve power. eDRX increases the time interval when a device is not paging the network. In the traditional mobile LTE network, the discontinuous receive window is 2.56 s. In the LTE-M network, the discontinuous receive window is extended to 43.69 min [8]. Reducing the number of times a device has to ping the nearest LTE tower can have significant power savings. In the SARA-R410M-02B, the average current consumption in the eDRX mode is 1.6 mA compared to 500 mA of current consumption when the device is transmitting into the LTE-M network [7].

IoT devices typically transmit and receive data intermittently. Power Saving Mode (PSM) allows devices to disconnect from the network and go into a low-power sleep state when it is not communicating. PSM is like being powered off, except the device remains registered with the network. When the device wakes back up, it does not have to reestablish its packet data network (PDN) connections and can start transmitting packets immediately [9]. In [7], the average current value in the PSM sleep state is 8 µA versus 9 mA of current when the device is on and registered with the network. PSM can allow LTE-M devices to last well over 10 years on two AA batteries [10].

Implementing a Device on an LPWAN

Devices communicating over the LTE-M cannot operate without a data SIM card. Less expensive development kits such as [1] and [2] require the additional purchase of a SIM card to get connected. Providers offering service in the LTE-M spectrum include Verizon, Vodafone, AT&T, T-Mobile USA, and Telstra, among others [2]. For instance, Verizon offers data plans for LTE-M devices starting for as little as $2 per month for device. In 2017, Verizon launched the first nationwide LTE-M network spanning 2.4 million miles [11].

Deploying an IoT development kit will require programming the on-board microcontroller. Popular software development ecosystems for IoT applications are Arduino and Mbed. Both Arduino and Mbed provide a C/C++ microcontroller software platform. The two platforms offer built-in libraries to connect devices to the internet and typical device tasks like reading temperature sensors and displaying to an LCD screen [12]. The development kits in [1], [2], [3], [5] are compatible with the Arduino ecosystem.

IoT development kits can be powered through a USB port or a battery. In [2], a USB port supplies 5 V of power and charges the board's lithium-polymer (LiPo) battery. When the USB power supply is disconnected, the board becomes battery-powered [2]. The development kits in [3], [5] also feature similar USB and battery power capabilities. Battery power is vital for IoT applications that do not have access to a consistent power source.

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