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HETEROGENEOUS WIRELESS: DUAL LORA-NB-IOT REDUNDANT CONNECTIVITY

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ABSTRACT

LoRa refers to a digital wireless data communication technology that enables very-long-range transmissions with low power consumption. Narrowband Internet-of-Things (NB-IoT) refers to a lower power standard focusing on indoor coverage. By combining LoRa and NB-IoT technologies, a low-energy device may receive the benefit of NB-IoT throughput, while consuming an amount of power similar to LoRa. The embodiments presented herein emulate a LoRa device over a NB-IoT network using a virtual gateway.

Power usage of a device can be reduced by using LoRa and waking up NB-IoT on demand. A device may use LoRa as long as LoRa meets expected delivery ratio and timeliness criteria; the exact selection of which radio to use for each type of packet may be determined for each device by applying a machine learning profiler to the network at the beginning of the life of the device, with continuous learning thereafter.

Heterogeneous LoRa-NB-IoT devices can also improve the reliability of a transmission by using both radios in parallel and introducing a frame replication and duplicate-elimination technique for highly critical packets. Thus, a device may be protected against network outages on either side.

DETAILED DESCRIPTION

Hardware costs for LoRa and NB-IoT devices are decreasing quickly. Since these technologies have various strengths and weaknesses in terms of aspects like upload and download bandwidth, battery consumption, range, coverage, and the like, it may be beneficial for devices to support more than one radio type. It should be understood that while embodiments presented herein leverage dual radio on a single device by combining LoRa and NB-IoT, the concept can be expanded to any other Low Power WAN (LPWAN) radio, such as LoRa with CG-MESH or Wi-Fi Mesh.

For instance, LoRa devices consume low amounts of energy when performing tasks like uploading data from a sensor once every day or so. However, LoRa can be unreliable at times, and the quality of the coverage may vary. LoRa may also be very slow, and may not fully support features like firmware updating and return channels. While NB-IoT may be superior to LoRa in regard to certain functions, the cost of NB-IoT may not be affordable for constant usage.

In order to support both functions without increasing the complexity of LoRa or NB-IoT protocols, embodiments disclosed herein exploit the concepts of differentiated flows and virtual LoRa gateways. For example, an IoT device may support both LoRa and NB-IoT connectivity. LoRa is very efficient for sending daily data without requiring too much energy, but the bandwidth is very limited and the return path (download) is also very limited. NB-IoT, on the other hand, can be quite efficient in the download side, but the energy consumption of NB-IoT is much higher. Furthermore, NB-IoT relies on an operator network, whereas LoRa can be deployed privately.

Figure 1 illustrates an example of a LoRaWAN network architecture.

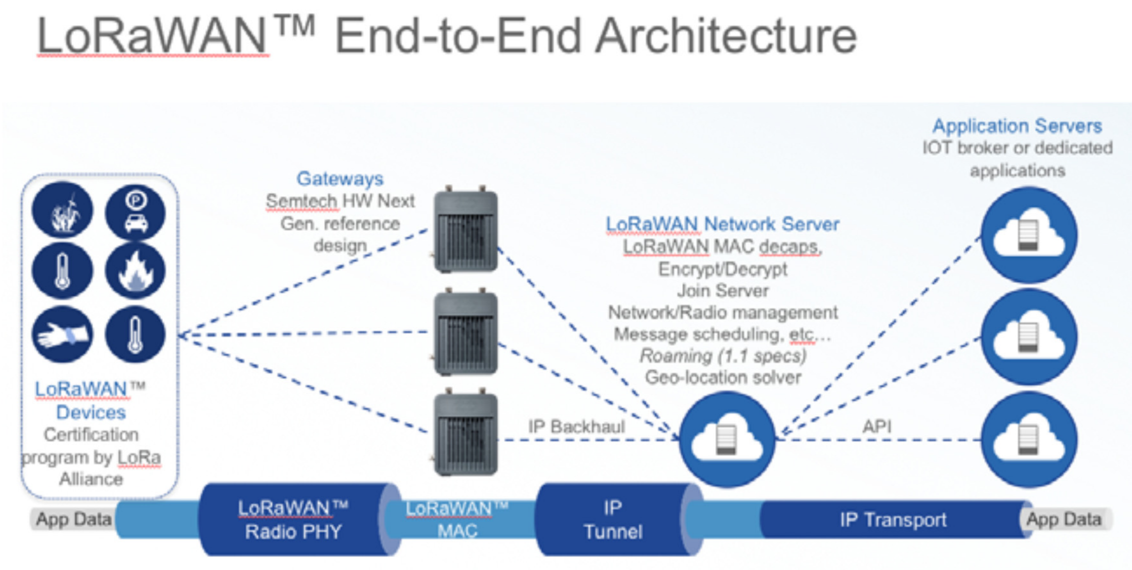

Figure 1

An architecture for a dual radio device is illustrated in Figure 2, which depicts a virtual LoRa gateway that appears as a LoRa gateway to a network server, but actually receives LoRaWAN packets encapsulated over NB-IoT.

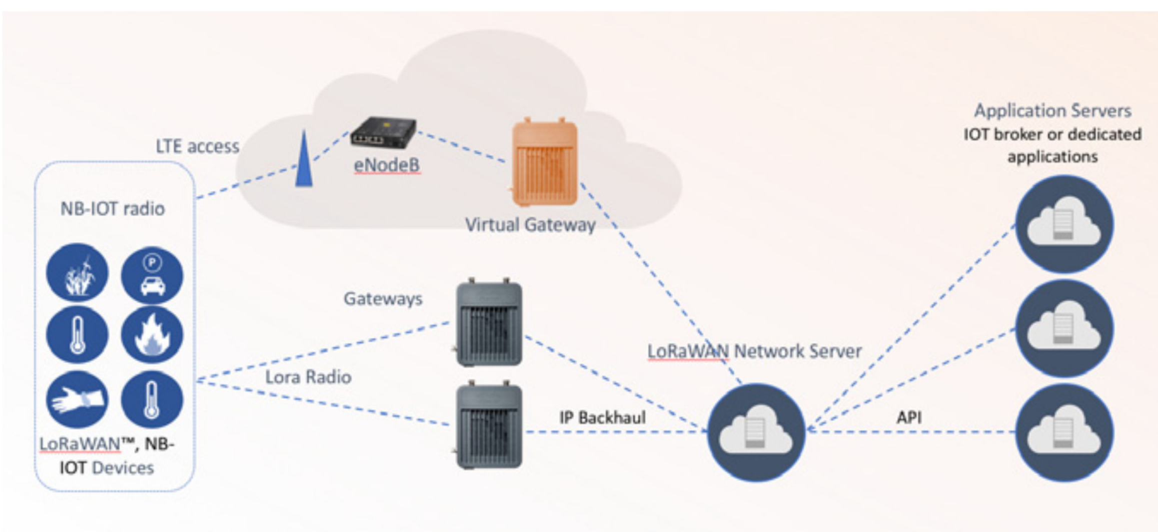

Figure 2

An IoT device, a mobile edge computing device located in the virtual gateway, or a network server determines the device flows and selects when NB-IoT is used in addition to, or as a replacement for, LoRa. As depicted in Figure 2, the IoT device use Long-Term Evolution (LTE) access for control data and NB-IoT control, whereas sensor data may instead use the LoRa radio. Download information and data may come from either LoRa or LTE access, and the IoT device may ask the network server to receive download data from LTE or LoRa according to different parameters like remaining battery, data information, etc. The virtual gateway may act as a normal LoRa gateway from the perspective of the network server, but the virtual gateway may forward download packets to the eNodeB. The network server may treat an upload stream coming from the virtual gateway as a normal LoRa stream, and the network server may decide the gateway (including the virtual gateway) through which it should send download information. Gateway selection may be based on predefined constraints such as power, data volume, bandwidth, etc. or the gateway may be requested by an application or the IOT device itself.

A dual radio device may use a single authentication mechanism that is valid for both access types. In this case, a secure communication link can be established between the network server and the LTE authorization server (not represented in Figure 2). The application session key may be the same for either server. Thus, a LoRa payload is tunneled on NB-IoT. Payload encryption may also be the same, and a data payload may be defined by LPWAN static context header compression (SCHC).

A return path, or downlink, may be provided through NB-IoT LTE access. An uplink may attempt to only use LoRa whenever possible, but may use NB-IoT as well in order to guarantee that critical packets are delivered, or to ensure the timely delivery of urgent packets.

LoRaWAN MAC-level controls may be added to profile packets and indicate a channel and spreading factor, as well as an indication of which radio type a class of packet may use. LoRaWAN MAC-level controls may also be added to indicate periods when the NB-IoT radio is turned on to transit or receive high volumes of data, e.g., to reflash the system or to upload a large measurement file. In between such times, the normal mode of the device may be LoRa class A or class B.

An additional header may be added to encapsulate the LoRa frame over NB-IoT; the header may include a time stamp and a source LoRa NetID, enabling the differentiation of packets between the NB-IoT network and the LoRa network. In the case of the LoRa network, this header may be added by the gateway based on the time of receipt of the first bit of the message and the device ID from the LoRa message. In the case of NB-IoT, the header may be added by the device, indicating a time at the beginning of the LoRa transmission, along with the device's ID. Using either approach may enable a network server to process the NB-IoT packets that arrive much sooner than the LoRa copies, discarding any LoRa copies with the same time and NetID when they eventually arrive.

The virtual gateway may act as a cache and scheduling (e.g., time of day) mechanism for functionality like firmware upgrades or configuration downloads. Machine learning techniques may be used to profile each device and determine on which path to send particular data of a given size and criticality, with a goal of optimizing power and guaranteeing a success ratio. The machine learning techniques may be based on learned power consumption, bandwidth requests, spectrum efficiency, application requirements, and the like. At the beginning of its life, a device may send most packets on both radios, and machine learning algorithm(s) may perform a continuous learning process whereby NB-IoT is used less and less to increase power efficiency.

Thus, the embodiments presented herein relate to the use of heterogeneous LoRa-NB-IoT communications, which may be achieved by emulating a LoRa device over a NB-IoT network using a virtual gateway. Power usage of a device can be reduced by waking up NB-IoT on demand and using LoRa otherwise. The decision to use LoRa or NB-IoT for a given type of packet can be determined according to machine learning techniques. Heterogeneous LoRa-NB-IoT devices also can improve the reliability of a transmission by using both radios in parallel, thereby protecting a device against network outages on either side.