# Demo Abstract: PlanIt and DQ-N for Low-Power Wide-Area Networks

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## ABSTRACT

Low-Power Wide-Area networks promise to deliver limited IoT payloads reliably at distances in excess of 10 km raising the possibility of thousands of IoT devices connected to a single base station. PlanIt is a web application able to visualize connectivity in these large-scale deployments prior to deploying hardware or even making a single signal-strength measurement. DQ-N is an adaptation of distributed queuing, a hybrid MAC protocol, compatible with current LoRa packet radios that significantly increases the number of nodes that can be supported from a signal base station. This demo will allow users to visualize LoRa coverage for the entire USA and demonstrate DQ-N using several sensor nodes.

## CCS CONCEPTS

**•Networks →Network protocol design; Network simulations;**

## KEYWORDS

Internet of Things; Low-Power Wide-Area Network

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## 1 INTRODUCTION

In many Internet of Things (IoT) applications, devices store data locally and then periodically communicates to the cloud via a gateway device. Therefore, one of the bottlenecks for scaling up the network is to overcome the limit of traditional low-power wireless technology (Bluetooth, WiFi, 802.15.4), whose typical range is less than 100 meters. There have been several recent attempts, such as LoRaWAN, Ingenu, and SigFox, to address this challenge in low-power wide-area networks (LPWAN). However, with these solutions several challenges remain [5]. In this demo, we present our solutions, PlanIt and DQ-N, to two of these challenges, specifically:

(1) visualizing network coverage over a large area prior to deployment,
(2) and improving network utilization to support a large number of nodes.

PlanIt is a LPWAN planning tool which takes geographic and demographic information into account to compute more realistic LPWAN network coverage. DQ-N is a distributed queueing based protocol designed to significantly increase the capacity of highly utilized LPWAN networks.

## 2 RELATED WORK

The LoRa Alliance specifies LoRaWAN, a protocol designed for low-cost IoT networks [7]. Its MAC layer is very lightweight and essentially implements pure-ALOHA, resulting in low channel utility under high traffic load due to packet collisions that results in a limited maximum node density [1].

Random-FDMA (R-FDMA) has been developed with the goal to minimize the manufacturing cost for IoT devices [3]. A typical R-FDMA base station would be implemented using a software defined radio (SDR) to sample the available spectrum and then perform all RF signal processing in software. This requires significant bandwidth between the SDR and host processor and enough processing power to process the received signal in real-time.

Low-power IoT coverage planning and network simulation are emerging topics [2, 4, 6, 10]. However, none of these planning simulation use both geographic and demographic information to generate test points and evaluation radio propagation. Therefore, these planning tools provide less useful insights on network coverage prior to deployment.

## 3 PLANIT

PlanIt is a web application that selects potential IoT device locations within a region that reflect the local demographic characteristics. From the generated locations, users can select the location of designated gateway devices. Then we use the Irregular Terrain with Obstructions Model (ITWOM) 3.0 to compute the path loss from each device to every gateway. If there is a gateway device within the link budget of the radio, a network connection is possible. The link loss information can then be used in a network simulator to produce realistic packet errors. The coverage map in Philadelphia generated by PlanIt with 500 test points and a single base station is shown in Figure 1a. Plath loss versus number of base stations is shown in Figure 1b.

During the demonstration, users can specify simulation parameters such as the location of the simulation, the number of nodes, and the radio transmission parameters. PlanIt will provide users a visual representation of network coverage for any location in the United States.


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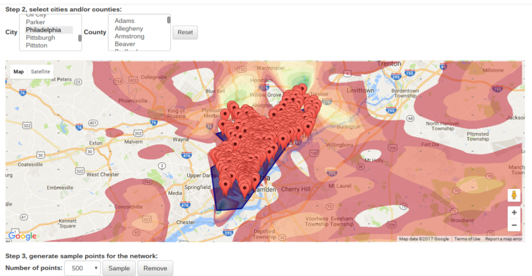
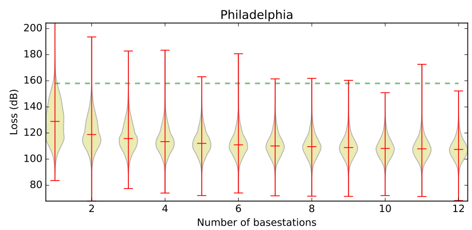



**(a) Computed LPWAN coverage for Philadelphia, Pennsylvania computed using PlanIt.**




**(b) Path loss in Philadelphia, Pennsylvania vs. number of base stations.**

**Figure 1: Demonstration results from the PlanIt web application.**

## 4 DQ-N

Distributed queuing (DQ) is a hybrid media access control protocol where the coordinator broadcasts contention-free transmission queue values to individual devices in response to contention-based transmission requests. Each device in the network maintains two queue lengths, namely the contention resolution queue (CRQ) and data transmission queue (DTQ). Using only this information, devices can compute contention-free transmit times in a fully distributed fashion. Although DQ can be implemented in the frequency domain, we focus on the time domain as we plan to exploit different frequency channels to increase network capacity. A more detailed explanation of traditional DQ is provided by Xu and Campbell [8].

DQ-N is an adaptation of traditional distributed queuing designed to be compatible with LoRa LPWAN packet radios [9]. It features adaptive transmission rate, upstream data slot acknowledgment, and low protocol overhead. The frame structure is shown in Figure 2.

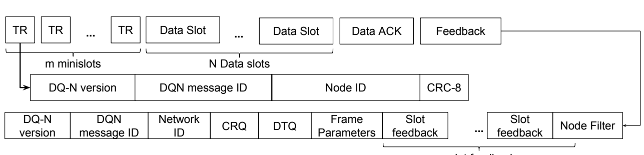



**Figure 2: DQ-N frame structure.**

The name DQ-N comes from the fact that there are up to N data transmission slots in each frame. Each device can request multiple data slots and various encoding rates in each transmission request (TR). To save bandwidth, one upstream data acknowledgement is sent at the end of the frame containing a bitmask of the acknowledgements from all data slots. Compared to ALOHA-style network, DQ-N networks can support significantly more nodes by reducing contention. For example, a single DQ-N base station can support 5,712 nodes generating 30-bytes per hour of upstream traffic (36-byte packets), as shown by the dashed line in Figure 3.

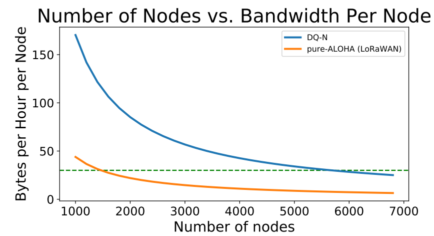



**Figure 3: Maximum number of nodes vs. upstream data rate supported by a single base station.**

In the demonstration, we will demonstrate several DQ-N sensors using Adafruit Feather development boards as nodes and a Raspberry Pi 3 as a base station. The setup is shown in Figure 4. An external monitor will be connected to Raspberry Pi to show the packet receptions and channel utility.

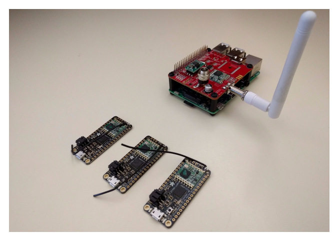


**Figure 4: Demonstration setup with 3 Adafruit Feather M0 RFM95 boards and 1 Raspberry Pi 3 with LoRa Radio Hat.**

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