# Demo Abstract: A LoRa Wireless Mesh Networking Module for Campus-Scale Monitoring


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## ABSTRACT

LoRa, an emerging wireless technology, is examined for long range communication performance in a large area. Although LoRa shows good performance for long-distance transmission in the countryside, its radio signals can be attenuated and interfered with by buildings, trees and other signal sources. In urban areas, our observation shows that LoRa requires a dense deployment of LoRa gateways to ensure that indoor LoRa devices can transfer data back to remote servers. Mesh networking is a solution for increasing the communication range and packet delivery ratio without the need to install additional LoRa gateways. This study presents our design of a LoRa mesh-networking module for IoT applications (e.g.,collecting data from multiple, widely distributed sensors on a university campus). We deployed 19 LoRa mesh-networking devices distributed in an 800m by 600m area on campus to serve as a gateway and to collect data at one-minute intervals. The results show our LoRa mesh networking module achieved a 88.49% packet delivery ratio (PDR), while the LoRaWAN in star-network topology was only 58.7% under the same conditions.


## CCS CONCEPTS

• **Hardware → Networking hardware • Networks → Network reliability**


## KEYWORDS

LoRa, wireless mesh network




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## 1. PRELIMINARY DESIGN AND RESULTS

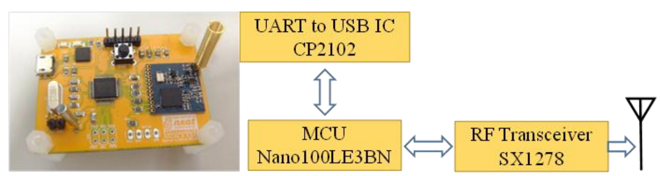


**Fig. 1 LoRa wireless mesh network module.**

LoRaWAN[1], based on LoRa technology[1], is a network standard for telecom operators to provide network service and enabling devices to transfer data to remote servers wirelessly. LoRaWAN, due to several design considerations, uses a star-network topology for communication between LoRa gateways and devices; only one hop is allowed between a gateway and a device. According to our observations, indoor LoRa devices may still be unable to communicate wirelessly with a nearby gateway, due to physical obstacles that can attenuate wireless signal strength and result in data losses and communication errors. We designed a LoRa wireless mesh-networking module to alleviate this problem. Fig. 1 shows a picture of the module. It is based on Nano100LE3BN, an ARM M0 microprocessor, and a Semtech SX1278 LoRa RF transceiver. All mesh networking protocols are run in ARM M0. This module can act as a radio module, like XBee, to accept commands from an application processor; therefore, the application processor can use this module as a network interface, so there is no need to worry about how the wireless network is formed.

In the following, we introduce our design. In the initial stage, the ***Gateway*** will broadcast beacons to invite other ***LoRa nodes*** to join its network. A LoRa node hearing the beacon from the nearby Gateway may join this network and set the gateway as its network parent. After that, the Gateway may query data from his children LoRa nodes, and the data messages reported from the LoRa node will also function like a beacon for other nearby nodes to hear and consider to joining the network.

As the example in Fig. 2 depicts, Node 1 joined the network and set the Gateway as its parent. After that, the Gateway queries the data from its child, Node 1 ($M_1$ in Fig. 2), and Node 1 reports its data ($M_2$) to the Gateway. The nearby Node 3 overhears the message $M_2$ ($M_2$ is acting as a beacon for Node 3), and Node 3 joins the network by setting its parent as Node 1. Node 1 will notify the newly joined Node 3 to its parent, the Gateway. Therefore, in the next query round, the Gateway will query Node 3 to gather its data using the message transmission sequence $M_3$, $M_4$, $M_5$ and $M_6$. Based on this method, all the nodes can join this multi-hop wireless mesh network, and the Gateway can query data on all the nodes.

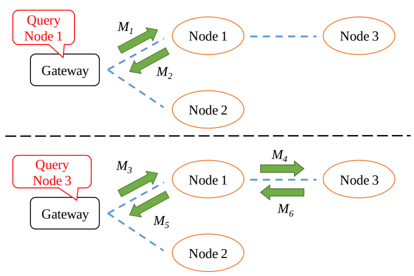


**Fig. 2 Procedure for a node joining the network and querying the gateway**

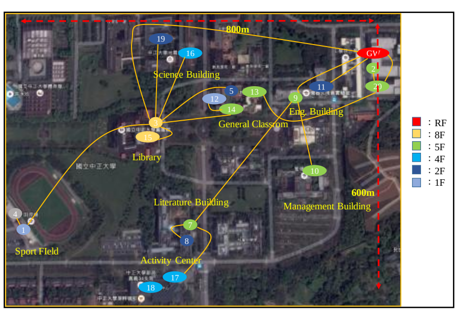


**Fig. 3 A network topology snapshot of the LoRa mesh network devices distributed around the university campus.**

The following experiment demonstrates 19 LoRa nodes (originally we installed 20 nodes, but Node 6 was missing during the experiment) distributed in an 800m by 600m area of a university campus, for the gateway to collect data at one-minute intervals for eight days. The results show our LoRa mesh-networking module can dynamically form a wireless mesh network, as a network topology snapshot shows in Fig. 3. The color filling the circle with a node number indicates on which floor of the building it is installed (i.e, 1F or RF). The node at 1F, like Node 12, needs other nodes' help to relay its data to the Gateway (denoted by GW in Fig. 3), because it cannot communicate with the GW directly. In this case, Node 14 at 5F and Node 3 at 8F help Node 12 to relay its data to the GW. Fig. 4 shows how the GW and nodes were deployed in this experiment. Please note that the GW uses a 3 dBi, 70 cm-long antenna installed on the roof of the building, and the nodes installed indoors use a 0.7 dBi, 2-cm antenna, to simulate usage scenarios of the real world. All nodes were installed at locations not in line-of-sight to the GW.

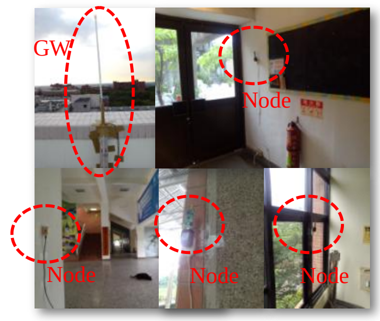


**Fig. 4 The pictures of GW and nodes deployed in this experiment.**

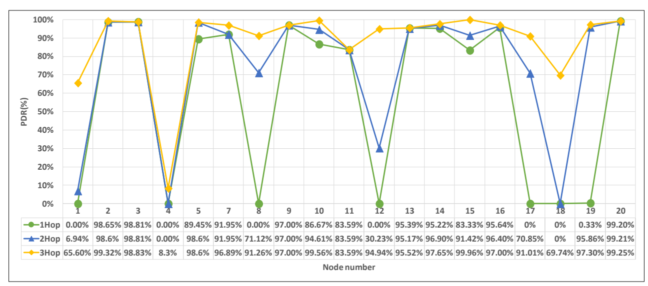


**Fig. 5 The package delivery ratio (PDR) under different hop-count(s) constraints.**

Fig. 5 shows the end-to-end package delivery ratio (PDR) under different limited hop counts. In this figure, ***1Hop*** indicates that all nodes can only connect to the GW with one hop. The performance of 1Hop can be considered as LoRaWAN, which uses one-hop / star-topology. We can see that the PDRs are low (some PDRs are 0%, with no data transferred to the GW, i.e., Nodes 1, 4, 8, 12, 17, 18 and 19). For these nodes, except Node 4, the PDRs were raised significantly if the hop-count constraint can be relaxed to ***3Hop***, indicating that a node can use at most 3 hops to deliver data to the GW. For example, the PDR of Node 12 is 0% at 1Hop, and rises to 94.94% at 3Hop. The average PDR for 1Hop is 58.7% and 3Hop is 88.49%. These results demonstrate that the proposed solution can significantly increase PDR without deploying an additional GW.

## REFERENCES

[1] LoRa Alliance, Retrieved March 9, 2017 from http://www.lora-alliance.org/