MobileDeluge: A Novel Mobile Code Dissemination Tool for WSNs

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***Abstract*—In this demonstration we present MobileDeluge, a general mobile network-reprogramming tool based on Deluge for wireless sensor networks (WSNs). MobileDeluge effectively addresses the weaknesses of Deluge and other traditional over-the-air reprogramming approaches for WSNs. It enables efficient code dissemination for *heterogeneous* WSN motes regularly operating over low-power links through a mobile base station. MobileDeluge has been evaluated in a real-world outdoor environmental WSN testbed.**

I. INTRODUCTION

Over-the-air programming (OAP) through wireless communications has been proposed in the past years to ease the cumbersome work of updating the applications for wireless sensor networks (WSNs). Compared to indoor deployments, real-world outdoor WSN deployments usually have some unique features which are very challenging when considering OAP.

First, heterogeneity becomes a common scenario in WSN deployments, where multiple node platforms (e.g., MICAz, IRIS, TelosB), sensors, and applications may coexist on the same WSN testbed. From this arises the need for point-to-point or subset reprogramming in WSNs. Second, real-world outdoor WSN deployments usually work over low-power link layers for better energy efficiency. Sleep intervals in low-power listening (LPL) mode largely extend per-packet delivery time. Since reprogramming usually involves bulk code image dissemination, the total delay is significant.

On the other hand, long-term outdoor WSN deployments would usually require periodic on-site maintenance visits (e.g., battery replacement and faulty node fixing) to keep the network operating in a healthy and sustainable manner [1]. In view of this, we introduce a novel concept of mobile code dissemination, and present MobileDeluge, a general mobile network-reprogramming tool based on Deluge [2]. Equipped with a gateway laptop and a base station, as shown in Fig. 1, MobileDeluge is a hand-held code dissemination tool for outdoor WSN deployments over low-power links. The key idea of MobileDeluge is to establish an instant connection between the mobile Deluge base station and its target sensor nodes within one-hop neighborhood, where the target nodes are to be updated with the same new code image. Once the connection is established, the target nodes are asked to switch to a different channel and disable LPL so that they can be reprogrammed efficiently with the MobileDeluge.

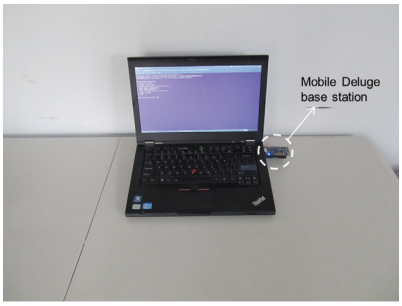

Figure 1. MobileDeluge, a hand-held mobile code dissemination tool.

II. DESIGN

In this section, we outline the design of MobileDeluge. Our design of MobileDeluge has the following key features: 1) one-hop network reprogramming, so that the reprogramming of a multi-hop network will be achieved by its mobility; 2) a novel control service enabling the retrieval of the platform information of the nodes in a one-hop neighborhood of the MobileDeluge base station (referred to as MobileBase), so that only the target nodes of the same platform type are reprogrammed at a time to address the heterogeneity; and 3) both MobileBase and the target nodes switched to a different channel with LPL disabled, allowing the fast and efficient transmission of the new code image without the interference to the rest of the network. In the following subsections, we present our design features. Please see [3] for details.

A. Subset Reprogramming

MobileDeluge's logic is split into two parts: the MobileBase side and the node side.

1) MobileBase: The MobileBase receives commands from the gateway, and then broadcasts to the nodes. We divided the commands into two sets. The first set is the regular Deluge commands, which is directly processed by the standard Deluge logic. The other set, referred to as *Mobile commands*, is used for communication between the MobileBase and the target nodes. Basically two Mobile commands are defined: DISS and ABORT. In order to notify the target nodes, the MobileBase starts issuing a DISS command, which is broadcasted in the original channel of target nodes with LPL enabled. If all the target nodes replied, the MobileBase switches to a new channel and disables LPL. Otherwise rebroadcasting is needed until the maximal number of retransmissions is reached. When the

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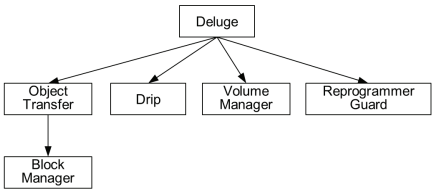
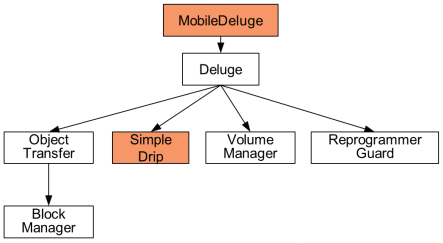


(a) Deluge code structure



(b) MobileDeluge code structure

Figure 2. Code structure of Deluge and MobileDeluge.

MobileBase and the replied target nodes are on the new channel, over always-on links, regular Deluge commands will be issued to complete the reprogramming. On the other hand, ABORT command can be issued at any time to reset the nodes to their original states (i.e., original channel, LPL enabled).

2) Node: When a node operating in the regular application (i.e., original state) receives a Mobile command packet, it checks the target list in the command packet. If it is not in the target list, the command is ignored. Otherwise, it sends a reply to the MobileBase if a DISS command is received and waits for an acknowledgment. If the reply packet is acknowledged, it switches to the new channel, and disables LPL, getting ready for reprogramming; otherwise, if no acknowledgment is received after several retransmissions, it ignores the command. On the other hand, if the command is ABORT, it resets to the original state immediately.

When a node switches to the new channel, it waits for Deluge commands to finish the reprogramming. A reset timer is started to reset the node to the original state in case of any error occurs during image transmission.

B. *SimpleDrip*

Since the reprogramming is limited to a single hop in our design, we replaced the multi-hop dissemination protocol Drip with a simplified version, referred to as SimpleDrip. Different from Drip, where every node periodically broadcasts according to the Trickle timer, in SimpleDrip, the sender node broadcasts the packet following a linearly increasing timer, whereas receiver nodes do not transmit any packets. The code structure of MobileDeluge is shown in Fig. 2 (b), in comparison with the code structure of the original Deluge shown in Fig. 2 (a).

C. *Mobile gateway*

We developed the MobileDeluge gateway software, which runs on the laptop and controls the reprogramming cycle. It integrates the Mobile commands and the Deluge commands. MobileDeluge hence can form as a potential generic mobile command/query system for WSNs, with some extensions.

Figure 3. A map of the ASWP testbed indicating the relative locations of the base station and the nodes in 5 sites.

Currently only two Mobile commands are implemented, as described above.

III. Real-world Evaluation

We evaluated MobileDeluge by reprogramming a subset of the nodes in the outdoor ASWP WSN testbed [1]. ASWP testbed contains 5 sites of sensor nodes deployed in different locations (Fig. 3). We wirelessly reprogrammed the nodes in sites 1, 2 and 4 using MobileDeluge, moved to a different reprogramming neighborhood at a time, and record the cost of disseminating a 50064 bytes' code image to the target nodes. The result is shown in Table 1. It can be shown that with subset reprogramming, per-node reprogramming cost is very low.

TABLE I. Statistics of Reprogramming in The Field

Target subset size	Type	Total Packets (DATA, ADV, REQ)	Completion Time (s)
1	IRIS	1196	63.95
1	IRIS	1172	74.94
1	MICAz	1219	87.93
1	MICAz	1214	65.95
1	MICAz	1195	72.94
3	IRIS	1257	68.94
3	IRIS	1283	72.94
3	MICAZ	1890	89.93
3	MICAZ	2115	55.96
4	MICAZ	2208	108.92
Total 21 Nodes	--	14749	762.42
Per Node Avg.	--	702.33	36.30

Acknowledgments

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References

[1] M. Navarro, T. Davis, Y. Liang, and X. Liang, "A study of long-term WSN deployment for environmental monitoring," in *Proceedings of PIMRC*, September, 2013.

[2] J. W. Hui and D. Culler, "The dynamic behavior of a data dissemination protocol for network programming at scale," in *Proceedings of SenSys*, 2004.

[3] X. Zhong, M. Navarro, G. Villalba, X. Liang, and Y. Liang, "MobileDeluge: Mobile Code Dissemination for Wireless Sensor Networks," the 11th IEEE International Conference on Mobile Ad hoc and Sensor Systems (MASS), Philadelphia, Pennsylvania, October 28-30, 2014.