Poster: Atomic-SDN: A Synchronous Flooding Framework for SDN Control of Low-Power Wireless

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Abstract

We present Atomic-SDN, a highly flexible framework capable of dynamically scheduling synchronous flooding phases to accommodate multiple traffic patterns resulting from application-level requirements. Specifically, Atomic-SDN accommodates the complex and varying traffic generated in a Software Defined Networking (SDN) control solutions for low-power wireless networks, where the high-overhead and centralized nature of SDN causes considerable problems due to the constrained nature of the network. By utilizing the high-reliability and low-latency properties of synchronous flooding, our results show that Atomic-SDN is capable of providing minimal bounded latency guarantees for network-wide SDN operations. This reduces the time to perform SDN operations on all nodes by orders-of-magnitude, and allows core SDN concepts to be pushed to the very edge of IoT networks.

1 Introduction and Motivation

SDN architecture gives network operators the power to abstract the complex management of network resources, provision these resources for multiple concurrent applications or operators, and easily roll-out new functionality. Not only can new behaviour be implemented on-the-fly, but network resources can be easily sliced on a per-application or per-tenant basis. When this concept is applied to the Internet of Things (IoT), SDN offers new opportunities and new business models, such as re-purposing old infrastructure or enabling multi-tenant networks. However, Software Defined Networking is a high-overhead concept that performs both asynchronous and scheduled communication between network devices and a controller. This control traffic can be placed in three distinct categories. *Collection*, where a controller gathers network state information in order to make informed decisions (topology, energy, link quality, etc.); *Configuration*, allowing the controller to configure the network by setting flowtable entries on individual nodes; and *Reaction*, where nodes can asynchronously solicit the controller in order to receive instruction on how to handle new flows. The plurality of traffic patterns required to achieve all three of these core SDN functions presents significant difficulties when trying to apply SDN to low-power wireless mesh networks. Here, the realities of limited radio and network resources clash with the low-latency and high-throughput requirements typical in traditional SDN implementations.

Current approaches for delivering SDN control in low-power wireless operate on top of the IEEE 802.15.4 stack [5, 1], where the considerable overhead generated by SDN has to coexist with the overhead from other protocols, such as Routing Protocol for Low-Power and Lossy Networks (RPL) [2], and IPv6 over the TSCH mode of IEEE 802.15.4e (6TiSCH) [10]. Managing this overhead and coexistence on top of existing Medium Access Control (MAC) layers like Carrier Sense Multiple Access (CSMA) or Time-Scheduled Channel Hopping (TSCH) is a not-insignificant challenge, and the time taken to fully configure every node in a SDN controlled mesh can run into tens of seconds, or even minutes.

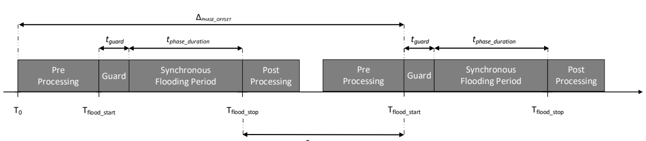

Figure 1. Atomic-SDN abstract flooding *phases* with pre and post phase logic.

Figure 2. Atomic-SDN high-level scheduling of SDN operations.

The separation of data and control planes in a multi-hop network is a topical research challenge [6], and critical for achieving SDN in low-power wireless. Atomic-SDN utilizes the *one-to-all* properties of synchronous flooding to quickly

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disseminate controller instructions across the network, and provides a flexible framework, protocol builder, and scheduling layer to dynamically run synchronous flooding protocols capable of *many-to-one* and *one-to-many* and *one-to-one* communication (used in the SDN *Collection* and *Reaction* operations). We evaluate Atomic-SDN through simulation, and show that the use of synchronous flooding in the control plane allows SDN operations to be completed orders-of-magnitude faster than existing solutions, whilst guaranteeing a bounded minimal latency.

2 Abstract Protocol Builder and Scheduling

To achieve the multiple traffic patterns necessary to facilitate the SDN *Configuration*, *Collection*, and *Reaction* operations Atomic-SDN abstracts lower-layer *one-to-all* synchronous flooding (such as Glossy [4] or other base synchronous flooding protocols ([8, 9] away from higher level protocol logic. Figure 1 shows how wrapping flooding periods with configurable pre and post logic functions, and then grouping these into abstract *phases*, simple flooding primitives can be constructed.

Atomic-SDN strings together these flooding primitives with transitional logic, allowing more complex operations. This enables Atomic-SDN to construct multiple high-level synchronous flooding protocols, such as CRYSTAL[7] and LWB[3]. Figure 2 demonstrates how these protocols can then be scheduled in response to SDN control requirements, enabling the SDN controller to indicate to the network which SDN operation is to take place, and which synchronous flooding protocol should be used in order to perform that operation. This allows Atomic-SDN to be used to slice the network into control and data periods, where the SDN layer is able to configure the low-power wireless stack through the dissemination of SDN flowtable instructions.

3 Evaluation

We demonstrate the performance gains Atomic-SDN achieves over current SDN architectures for IEEE 802.15.4 through implementation in Contiki and simulation in Cooja. Figure 3 demonstrates how Atomic-SDN manages to perform a round-trip SDN *Reaction* operation, requiring a node to solicit the controller for instruction and then receive a response, on all network nodes in less than a second. In comparison, Whereas the a SDN framework operating on top of the IEEE 802.15.4 network layer require tens of seconds (with CSMA) or even minutes to associate every node (using an energy-saving mac with radio duty cycling).

4 Conclusions

The framework presented in this work allows SDN architectures to capitalize on the reliability and low latency gains that have been highlighted in recent works on synchronous flooding protocols. Moreover, the one-to-many pattern inherent in network flooding allows SDN controllers to quickly distribute instructions to to the entire network, a key weakness in existing SDN solutions for low-power wireless. Crucially, Atomic-SDN can perform SDN operations for all nodes within a low-power mesh network in under a second, whereas SDN frameworks built on top of the existing IEEE 802.15.4 stack require tens of seconds, or even minutes, to complete the same task.

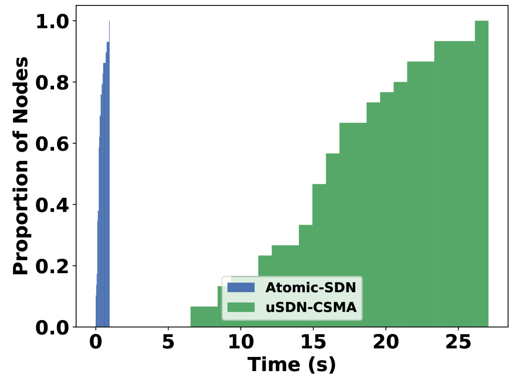

Figure 3. Time taken to perform a *Reaction* operation on all nodes in a in a 30 node mesh. Atomic-SDN (blue, far left), versus μSDN.

5 Acknowledgments

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