SDaN: Software Defined Adaptive Networking - IoT and Beyond

Jason J. Quinlan
Department of Computer Science
University College Cork
Ireland
j.quinlan@cs.ucc.ie

Abstract

In this position paper, I present my vision on how enhancing the interaction between devices in an Internet of Things (*IoT*) network and the mechanisms of Software Defined Networking (*SDN*) can not only improve the efficiency of wirelessly transmitted data but can strengthen the viability and manageability of devices in an IoT network and beyond. By expanding the composition of SDN to encompass not only the existing North (controller API), South (device API), East and West interfaces (distributed controller(s) API) - viewed as an X-/Y-axis, but also an holistic adaptive Z-axis, which mandates a higher layer abstraction of the root APIs irrespective of the underlying architecture.

This adaptive Z-axis improves the global view by offering an abstracted view of the network control and management for all objects in the network. In this proposal all interfaces, irrespective of axis, can be viewed as a single abstraction, by which *inter-operative function calls* can be leveraged adaptively between the device(s) and the network(s). By leveraging these additional constructs, I believe SDN can improve the capabilities and efficiency of IoT networks and beyond.

Categories and Subject Descriptors

D.2 [**Software**]: Software Architectures

General Terms

Design, Position

Keywords

IoT, SDN, Software Defined adaptive Networking, SDaN

1 Introduction

The explosion in quantity of IoT devices and variety of their underlying protocols are focusing researchers to consider novel mechanisms to control and manage the heterogeneity of devices and their underlying workflow - workflow is defined as a single task for one device or a chain of tasks across multiple devices. Typically, heterogeneous IoT devices communicate over a shared RF link, be this cellular, WIFI, bluetooth, zigbee, etc. These generally loosely coupled IoT networks can range from large geographical systems to single devices, with triggered tasks on the device(s) generally having different delay demands. Considerations in IoT range from WSN nodes which are typically resource-constrained and mandate bursty traffic (generally from many nodes at once) to large global multi-hop ad-hoc MANETS.

With this level of variety within the devices in mind, the design principals of Software Defined Networking (*SDN*), i.e. separation of control (traffic management) and data (physical traffic routing) planes, has proven successful in solving some of the problems and challenges faced by IoT. Typically, SDN has been proposed as a controller within the network. This design works perfectly as SDN can offer a means of efficiently and rapidly partitioning and routing the network based on the priority of the underlying IoT task(s).

Existing proposals that leverage interactions between IoT and SDN range from agile flow-tables within the devices to complex hierarchical architectures which enable flexible and efficient management of tasks and resources: [1] proposes a layered centralised SDN controller architecture that dynamically allocates differentiated quality levels to different IoT task in heterogeneous scenarios, [2] where the design of a data-plane in-sensor (in-band) flow-based packet forwarding model for WSN with centralised controller(s) is considered, [3] presents an SDN-IoT Architecture with NFV Implementation but "the scheduling must be built over defined routes" and [4] proposes IoT with SDN combined with NFV and mass data analytics for aggregation and interpretation.

These papers show how the underlying separation of control and data planes in SDN can improve the capabilities and efficiency of IoT networks but these systems are limited by the inadequacy of their global view, and the inherent constraints placed upon them by static SDN controller(s)/interfaces and defined routes. While [5], which propose a generic IoT protocol which provides integration between different IoT gateways and the interaction between their respective supported protocols, illustrating how the underlying IoT system can benefit from a higher level unified protocol. In the next section, I present my reasoning for a Z-axis holistic overview of the existing SDN APIs and why SDN must evolve to do more than simply route traffic, I then offer some questions raised and a conclusion.

2 Software Defined Adaptive Networking

As we have seen, SDN provides the promise of a single common framework by which all devices can interconnect, and communicate irrespective of transmission medium (cellular, WIFI, bluetooth, zigbee) and underlying routing behaviour. For future networks, including IoT, to evolve using an SDN ethos, these networks must do more than simply centralise the control element, and management the distribution of content within the network.

Considerations: When the network state is adaptive for devices and underlying transmission medium connections, how will a centralised controller inform the devices of the network state, when this view is possibly already out of date and incorrect. While initially WSN and IoT networks had an explicit number of devices, clearly defined workflows and static defined networks, current and future IoT networks are adaptive and dynamic in all of these areas, which mandates that unadaptive flow-based routing will not work.

Consideration must be given to the control models available in SDN [6] which provide flexibility of overall management design and these include centralised (where the controller is the bottleneck), distributed (where network state updates are the bottleneck) and hybrid systems which look to control/limit controller requests (pushing, flow aggregation) and placement of controllers (hierarchical, virtualised or merged). As SDN is adept at partitioning and routing the network, defining a so called "Quality of Route (*QoR*)", the next subsection will expand on the functionality required of Software Defined adaptive Networking (*SDaN*) to accommodate the holistic Z-axis abstraction.

Requirements: As alluded to in [5] an adaptive abstracted system is required to negotiate with devices that utilise TCP/IP and those that do not. As the majority of IoT nodes are typically focused on a single series of tasks, with limited overall impact on system architecture, these IoT devices may benefit from a set of SDN defined *inter-operative function calls*, rather than just simple packet/flow routing. Benefits can be ascertained from permitting SDaN to execute function calls on the devices, and permitting the devices to execute function calls on the controller/routers: from controller to device, these function calls could be as simple as delaying, or revising time allocation for, workflows in WSNs to (re)evaluating QoE demands for multimedia content for mobile devices. While for device to controller, this may be as elementary as informing the controller a new device is connected (as in an ad-hoc network) to requests for increased priority/partitioning within the network. All facilitated by having access to the devices within the network and a holistic understanding of their needs.

While SDaN will move away from simple packet rerouting, existing issues such as replication of traffic on devices due to device(s) failing or insufficient routing capabilities (limited battery/CPU) must remain implicit in the overall framework. A decentralised SDaN controller, with an interdependent controller within each transmission medium network (WIFI, zigbee, etc.) will reduce issues of state change, while extending this to a distributed controller within devices, mandating not only SDN protocols within the devices, but actual control, especially for autonomous and intelligent devices, will improve overall efficiency and manageability of the network.

SDaN will not simply reactively control the network based on seen or determined flows but will evolve to proactively extract workflow knowledge from devices so as to predict and govern network demands: such as provisioning or slicing of network resources, partitioning of wireless channels, and providing fairness between all network devices. For devices, SDaN will counsel and harmonise based on the underlying management needs of their resources: such as regulating energy consumption, triggering of work-tasks, and synchronising time dependent network interactions.

3 Open Questions

While this position paper offers some insight into optimised integration of SDN and IoT, it also raises some unanswered questions: 1) Can NFV be used for dynamic instantiation of *inter-operative function calls* on devices and 2) When all devices can interact with the SDN controller, how will the controller constrain synchronisation issues, when devices mandate ever increasing priority demands.

4 Conclusions

The control mechanisms in SDN prove efficient for statically defined IoT networks but SDN must evolve beyond packet route management to offer the dynamic adaptation needed for IoT networks of the future. The framework proposed in this paper not only offers backward compatibility for legacy systems, but is adept to future adaptive or changing networks, such as Vehicle2Vehicle, disaster/emergency and multi AP Home networks: typically networks where users adapt in not only physical location but also connection(s) to the network. Not considered in this paper are security issues that may exist when all devices interact with the global view (access rules for authorised devices may limit this issue) and benefits offered by NFV integration, such as virtualising storage, hardware and computation (controller).

Acknowledgement This publication has emanated from research conducted with the financial support of Science Foundation Ireland under Grant 13/IA/1892, and is co-funded under the European Regional Development Fund under Grant 13/RC/2077. The author would also like to thank the anonymous referees for their valuable comments and suggestions.

5 References

[1] Z. Qin, G. Denker, C. Giannelli, P. Bellavista, and N. Venkatasubramanian. A Software Defined Networking architecture for the Internet-of-Things. In *2014 IEEE Network Operations and Management Symposium (NOMS)*, pages 1–9, May 2014.

[2] T. Luo, H. P. Tan, and T. Q. S. Quek. Sensor OpenFlow: Enabling Software-Defined Wireless Sensor Networks. *IEEE Communications Letters*, 16(11):1896–1899, November 2012.

[3] M. Ojo, D. Adami, and S. Giordano. A SDN-IoT Architecture with NFV Implementation. In *2016 IEEE Globecom Workshops (GC Wkshps)*, pages 1–6, Dec 2016.

[4] Christian Jacquenet and Mohamed Boucadair. A Software-Defined Approach to IoT Networking. *ZTE Communications*, 1:012, 2016.

[5] A. Al-Fuqaha, A. Khreishah, M. Guizani, A. Rayes, and M. Mohammadi. Toward better horizontal integration among IoT services. *IEEE Communications Magazine*, 53(9):72–79, September 2015.

[6] Habinshuti Francois Xavier and Soonuk Seol. A Comparative Study on Control Models of Software-Defined Networking (SDN). *Contemporary Engineering Sciences*, 7(32):1747–1753, 2014.