Load Balanced Controller Association in Wireless Distributed SDNs

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***Abstract*—Wireless infrastructure is steadily evolving into wireless access for all humans and most devices, from 5G to Internet-of-Things. This widespread access creates the expectation of custom and adaptive services from the personal network to the backbone network. In addition, challenges of scale and interoperability exist across networks, applications and services, requiring an effective wireless network management infrastructure. For this reason Software-Defined Networks (SDN) have become an attractive research area for wireless and mobile systems. SDN can respond to sporadic topology issues such as dropped packets, message latency, and/or conflicting resource management, to improved collaboration between mobile access points, reduced interference and increased security options. Until recently, the main focus on wireless SDN has been a more centralized approach, which has issues with scalability, fault tolerance, and security. In this work, we propose a state of the art WAM-SDN system for large-scale network management. We discuss requirements for large scale wireless distributed WAM-SDN and provide preliminary benchmarking and performance analysis based on our hybrid distributed and decentralized architecture.**

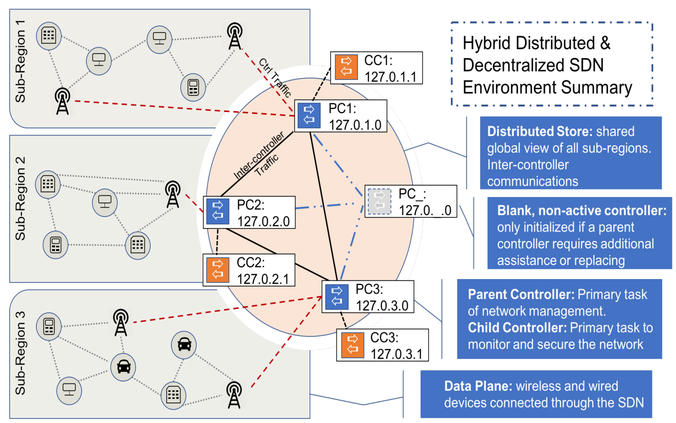


Fig. 1. Hybrid Distributed and Decentralized SDN Controller Architecture

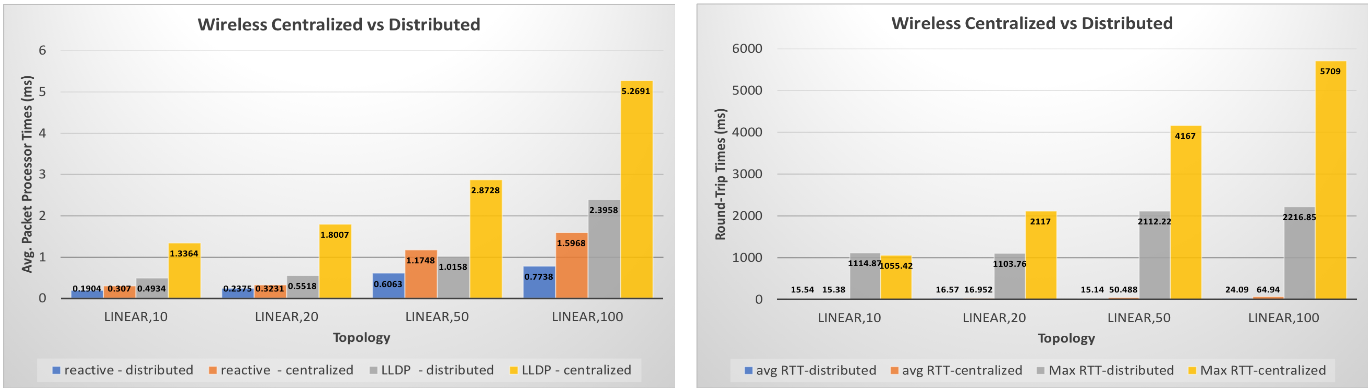
I. Introduction

As wireless and mobile (WAM) devices begin to out-number the entire human population, and wireless infrastructure from 5G to Internet-of-Things become prevalent, the expectation of custom and adaptive services from the personal network to the backbone network is now the imperative. With latest technology, WAM Systems can provide application-specific Quality-of-Service (QoS) to users, while also managing a dynamically changing environment. Coordination and management of large numbers of heterogeneous wireless and mobile devices is a significant challenge. From Internet of Things (IoT) devices to smart phones, ipads and laptops to Unmanned Air Vehicles (UAVs) to Small Satellites, interoperability and on-demand communication paths require an adaptive approach to network management. Software Defined Network (SDN) techniques can be employed to create a distributed SDN (D-SDN) management architecture for WAM systems.

II. Overview of SDN for WAM Systems

Software Defined Networking (SDN) is a networking paradigm in which the forwarding hardware is decoupled from control decisions. The network intelligence is logically centralized in software-based controllers (the control plane), and network devices become simple packet forwarding devices (the data plane) that can be programmed via an open interface. SDNs can be used to quickly assemble new services and infrastructure to meet dynamically changing environment objectives. There has been little investigation of heterogeneous SDN for large-scale, distributed WAM systems. Heterogeneous in this case meaning a distributed cluster of openflow controllers assigned with separate task to coordinate, secure and manage a network. The majority of SDN approaches have been applied to wired networks with common infrastructure and policy types. However, the flexibility of SDNs using a programmable controller provides great potential when applied to heterogeneous WAM environments, including industrial, IoT, mobile wireless, or any cyber-physical system. SDNs can help to quickly assemble new services and infrastructure to meet dynamically changing objectives.

A centralized abstract is a traditional key for SDN operation, since it strengthens the control capability of the SDN controller over the entire network [1]. In this approach, the controller is one entity and is responsible for determining routing paths, developing policies, partitioning the network, and other network administrative functionality. This creates a known vulnerability where the SDN controller becomes a single point of failure. For large-scale mobile wireless networks, this can create a challenge in terms of responsiveness to time-sensitive conditions, such as mobility, changing channel conditions, security vulnerabilities, and reliability. WAM-SDN solutions and heterogeneous SDN solutions must be fault tolerant and



(a) Wireless arch. packet processor

(b) Wireless arch. round-trip-times

Fig. 2. Comparison of packet processor service times and round-trip times for wireless centralized and distributed controller architectures

able to obtain or at least reliably estimate the centralized perspective (global view) to keep the SDN advantage of optimized network performance. To produce an efficient, reliable, and trustworthy SDN architecture, the coordination among distributed/decentralized controllers must be considered.

III. Hybrid Distributed Decentralized SDN Architecture

Due to the limitations discussed of a centralized approach for SDN, we have proposed a hybrid distributed and decentralized (HDD), adaptive SDN architecture for efficiently managing any wireless or mobile communication network. Our proposed architecture, as shown in Figure 1, will monitor network performance metrics in the data plane (i.e. available bandwidth, packet latency and jitter, number of dropped packets, etc.) and performance metrics in the control plane (i.e. number of nodes, number of links, bandwidth available versus past values, induced delays, amount of inbound and outbound control packets, the controller processing capacity, etc.) to create a model that constantly calculates the optimal number of controllers needed to be activated/deactivated in a decentralized or distributed fashion for sustaining peak network performance. To keep the switch-to-controller delay lower, many controllers are desirable, however many controllers lead to complex maintenance to preserve the global view of the network whilst introducing additional control packet overhead [2].

IV. Performance Evaluation

Experiments were conducted using mininet and extensions to emulate the data plane environment in a linear and ring topology. The linear topology creates a host node per switching device in the network (ex. ”linear,10” means 10 switches and 10 host devices). The ring topology creates a small set of switching devices in which each device connects to two other switching devices (ex. ”ring 5,10” means 5 switches and 10 host devices).The SDN controller used was the open-source network operating system ONOS. The test were conducted on a AMD A6-6310 APU with 4 cores.

Figure 2 demonstrates the comparison of the internal packet processor service times for wireless centralized and distributed controller architectures. In larger network topologies, utilizing the distributed design can reduce LLDP and reactive packet processing times by %55 and %52 while the average and max RTT decreased by %44 and %61 in wireless scenarios. The LLDP packet processor represents the service time of the controllers ability to process link discovery packets being transmitted for determining accessible nodes, switches, or APs within its control region. The reactive packet processor represents the service time of the controller’s ability to process flow request from communicating nodes within the data plane. Increasing the nodes size requires more LLDP packets to be generated for complete network discovery. The controller’s delay for processing reactive packets increased as the number of host requesting reactive paths to transmit messages increased.

V. Conclusions

This work proposes the development of a wireless HDD-SDN to 1) provide system fault tolerance in the event of controller failures and attacks, 2) offload network administrative functions to the cloud or other controllers for energy preservation, 3) offload controller functions to multiple nodes for load balancing, and 4) allow for distributed resolution of node failures and attacks. We observed when considering creating a system that allocates management responsibilities from a centralized controller to additional controllers in a cluster, parameters such as the LLDP, and reactive packet processor can be used as thresholds for determining the optimal number of controllers needed in a cluster to maintain a stable network in dynamically changing environments.

Acknowledgment

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References

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