

Ultimate Performance of Wi-Fi Access Points With Multiple Interfaces: An Application of Software Defined Network

Yu-Ju Lee^{*†}, Wen-Wei Liao[†]

^{*}Department of Computer Science, University of Colorado Boulder, Boulder, Colorado 80309-0430 USA

[†]University of Colorado Boulder, Cooperative Institute for Research in Environmental Sciences
at NOAA/OAR/ESRL/Global Systems Division

Yuju.Lee@Colorado.EDU, WenWei.Liao@Colorado.EDU

Abstract—Wi-Fi become the more popular wireless technology in our living environment. More than one wireless access point to assemble a wireless distribution system is not exclusive to the enterprise. However, current Wi-Fi protocol has no central control mechanism and efficiency cooperation mode between different wireless access points. In this research we proposed a wireless distribution system with software define network controller which provide the following properties. First, this system separates the control plane and data plane with different wireless interfaces. Second, different traffic flows from one access point to another could be assigned with independent, non- mutual interference channels if wireless resource is enough to achieve high throughput performance for whole wireless system. Third, the SDN controller is centralized unit and could execute the global channel optimization rather than regional channel optimization between two adjacent wireless access points. This system facilitated current wireless infrastructure to build the control plane. It utilizes the central Software Defined Networking (SDN) controller to collect required information from different access points, distribute resources to different access points and control the traffic flows. We demonstrate how wireless system with a central control unit could enhance the channel optimization and improve the whole system performance. Experiment to verify our idea is completed by Network simulation 3 (NS-3). The result shows with reasonable channel assignment, the wireless distribution system could optimize all wireless access points interfaces.

I. INTRODUCTION

With continuously develop standard, Wi-Fi is getting popular for daily usage, and it quickly became the dominant wireless communication system in enterprise, public area and individual house. With the increasing demand for the Internet access of end devices like smart phone, laptops and Internet of things(IoT) devices, it is obviously that single access point (AP) cannot satisfies those demands. In order to extend the coverage range and serve more end devices within Wi-Fi signal coverage area, there are some common mechanisms for Wi-Fi to achieve this goal such as repeaters, wireless distribution system (WDS) and wireless mesh network (WMN). However, there are some challenges and limitation exist of those mechanisms and thus could not optimized the limited frequency resource. We would discuss in the following section.

A. No channel selection optimization

Either repeater, WDS or WMN, there is one common characteristic for all of them, that is, they need to use one common channel between wireless AP (nodes) for their control plane and data plane. They use assigned channel to transfer protocol control packages and bunch of data between nearby nodes. However, this channel is selected when the first node activated and broadcast its beacons through channel it selected. Other nodes need to scan all possible channels, associate and authenticate with the first node to form a wireless system. Unfortunately, when more and more nodes join this wireless system, the spatial variation become a serious issue. The first node choose an initial channel based on its channel quality detection which only impact by its nearby environment. Therefore, first node select one channel which it think better than other channels. But the following joint nodes may not think it is a good channel to dwell because those nodes stay in different space than the initial node. Even the initial node has multiple interfaces, current existing mechanisms only use one dedicated interface and has no protocol to cooperate with other nodes to change assigned channel later. In short, we could conclude that the initial AP only has limited regional channel information rather than entire system information leads to this problem.

B. Limited link layer control ability

A repeater and WDS protocol are designed to process link layer packets. The function of repeater is quite simple, just to receive, check the completeness of packets, and then broadcast to the air again. All they can do is to expect other receivers which may included its target AP receive these packages with strong enough signal. Therefore, it only processes the forwarding feature. The WDS protocol is a little better than a repeater. It could allocate the corresponding MAC address then relay package to the target receiver. However both of these two mechanisms could not further process the incoming package. Therefore, it could not provide more controlled ability because it only has link layer information.

C. Uncontrollable routing path

Repeater, WDS and WMM can't control their per flow routing path. First, a repeater only enlarge received signal and broadcast to anywhere. If there is no directional antenna or corresponding reflecting environment, it is very natural that all the nodes which receive the broadcast packets will continue to broadcast those packets. For WDS, it will locate the destination MAC address. Therefore, the target node will receive and relay the packets. However, there is no methods to dynamic change the target MAC address. As a result, it is impossible to change the per flow traffic. For the mesh network, it will build the mesh topology depends on proactive or reactive routing protocol; however, it does not have the entire system information to decide node's routing information and dynamic select the optimization routing path based on per flow condition.

D. Not fully exploited the advantages of co-located multiple wireless network interface

For current commodity devices, access points with multiple wireless interfaces are become popular, that means they have ability and could establish multiple links between nearby access points if they both have multiple interfaces. However, even they have this potential capacities, there are few applications could optimize them. For example, users may consider load balance or backup mechanism between two links. The challenge to achieve this feature is that we need to design a new protocol or enhance existing protocol to fulfill these features. However, propose a new wireless spec take long time. Even we have this kind of protocol, we would only have regional information between any two nodes, and are almost impossible to adjust a wireless system with many nodes located in large area.

By all challenge above, we need to design a new control mechanism which could utilize access points' multiple interfaces, improve the entire wireless system's performance and adjust the per flow traffic by information of entire wireless system. Therefore, we develop a new mechanism to collaborate software defined network(SDN) controller with current wireless network infrastructure to accomplish the following features.

- Optimize the control path: we separate control plane and data plane with different wireless systems or interfaces if they provide.
- Optimize channel utilization: we want to collect each wireless node' capabilities like what kind of wireless interface it has through devoted control plane and allocate the different channels of traffic flows to optimize the throughput performance.

II. DESIGN

In this section, we introduce the design detail of our SDN collaborated wireless distribution system.

A. System architecture

The object of SDN collaborated wireless distribution system is to distribute limited wireless resources smartly to maximum the whole system performance. The performance index may be the throughput, latency, number of hops of routing and bandwidth usage. The SDN collaborated wireless system provides the two features. 1) Try to use all possible independent wireless interfaces to eliminate inner competition between nearby wireless devices. 2) Provide per flow assignment feature, which is defined by two access nodes transmit at the same channel 3) Build dedicated control plane through the current existence infrastructure for the compatibility.

B. System model

- There is a centralized SDN controller attached to the selected access point to integrate all information from different access points. Information includes kinds and numbers of wireless interfaces, current dwell channel, signal strength from peers and so on. In addition, this SDN controller also records a flow table to indicate which flow comes from which node and where it goes by what channel. The SDN controller could communicate with access points to assign, update their dwell channels for channel optimization.
- The wireless interfaces used to transmit data could be assigned and pair by the SDN controller. These interfaces work as standard infrastructure or ad-hoc mode. They accept the controller's command to change their dwell channel and report the packets number sent or received. The controller will decide where and when to forward packets to another wireless access points.

In this paper, we assume that each wireless node has more than one wireless interface and the external SDN controller has ability to immediately process the information and execute algorithms.

III. EVALUATION

In this section we shows how SDN collaborated wireless system could enhance the system performance by comparing with a wireless system with one access point and two repeaters. We conduct the experience with NS-3 by 3 nodes and each node has 3 wireless interfaces. Therefore, all 3 nodes could establish control plane by one dedicated channel and use other wireless interfaces as data plane to transmit packets. In this simulation we attach an external SDN controller to process the information from these 3 nodes. the connection between external controller and one of these three node is established by wire interface.

A. Flow traffic without SDN controller to coordinate

Figure 2 is designed to simulate the general scenario as our home environment - one main access AP and two repeaters. Two repeaters would forward any packets they receive from other devices to main AP. However, all three access points will be operated on the same channel and have mutual competitive frequency effect.

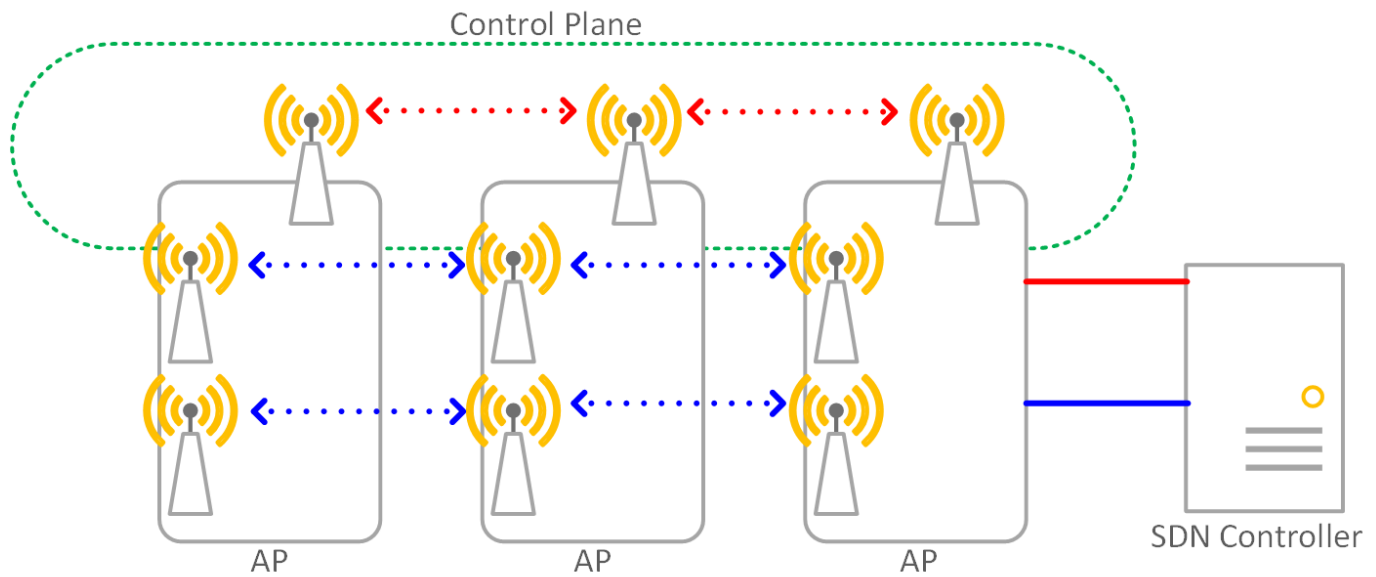


Fig. 1. Architecture of SDN collaborated wireless distribution network

Table I shows the clean environment throughput simulation. This is measured by one data flow goes through Node3 to Node1 without any other flow in the system. This is the maximum traffic capacity of this simulation scenario. However, when we start to run two flows in the system, they will start to compete with each other because the shared media. It causes the throughput for each node start to drop. Table II shows the simulation result. We could find each flow has only about half of the clear environment throughput because we do not assign the different priority. However, from the whole system view, even these three access points have multiple interfaces. They do not use and treat as redundant resource.

TABLE I
ONLY ONE DATA FLOW IN THE SYSTEM AT 5G CHANNEL

Number	Direction	Throughput
Flow 1	Node 3 to Node 1	21.24Mbps

TABLE II
TWO DATA FLOWS IN THE SYSTEM AT 5G CHANNEL

Number	Direction	Throughput
Flow 1	Node 3 to Node 1	12.62Mbps
Flow 2	Node 2 to Node 1	12.00Mbps
Flow 1+2	Node 2/Node 3 to Node 1	24.62Mbps

B. Flow traffic with SDN controller to coordinate

In the figure 3, we want to simulate the SDN controller which is used to coordinate the channel for different traffic flows. Because we leverage the existing infrastructure, we don't need to setup the control plane to exchange the control message. After the system is up, Node1, Node2, and Node3 will send messages to external SDN controller to report their

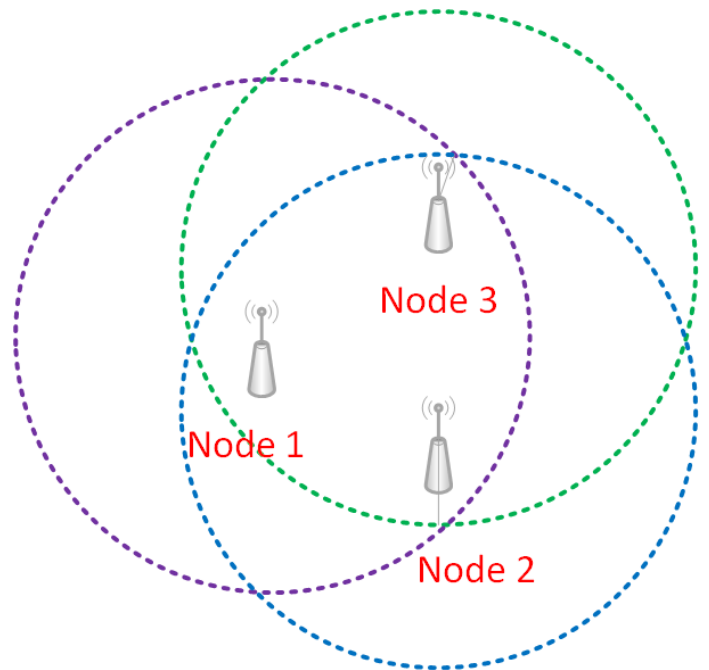


Fig. 2. Three nearby access points stay with the same channel and have physical overlap coverage range

abilities, which is the information about how many wireless interfaces they have. After receive these information. The SDN controller prepares the flow table to monitor the traffic flow. In this situation, when the flow1 was generated, controller will assign one 5G channel for this flow by assigning the wireless interfaces in Node1 and Node3 to transmit it. At the same time, when flow2 was generated, the SDN controller will check its flow table and find this system still has another

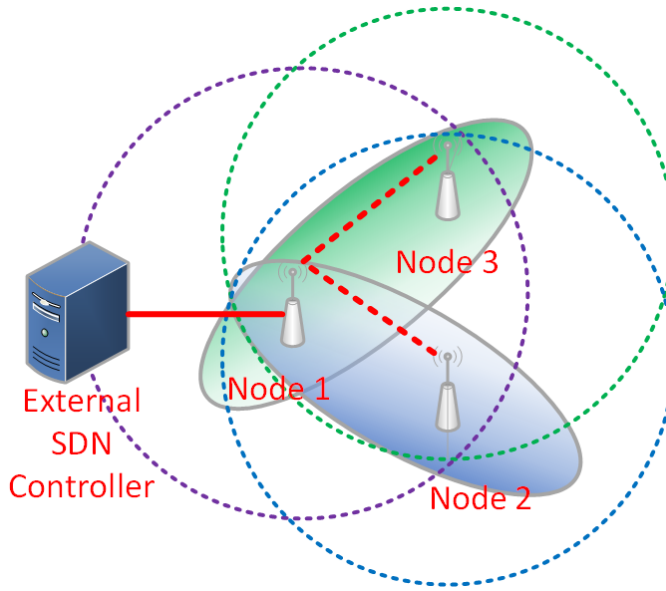


Fig. 3. Three nearby access points with SDN collaborated

pair of wireless interfaces could be facilitated. Therefore, it will assign interfaces on Node1 and Node2 to another un-overlapped 5G channel to transmit flow2. Table III shows the results of this simulation. We could find the total throughput of this system is 36.44Mbps which is better than the scenario before.

TABLE III
5G: TWO FLOWS IN THE SYSTEM

Number	Direction	Throughput
Flow 1	Node 3 to Node 1	15.40Mbps
Flow 2	Node 2 to Node 1	21.04Mbps
Flow 1+2	Node 2/Node 3 to Node 1	36.44Mbps

IV. RELATED WORK

Integrate a SDN controller with different kind of wireless network can be used in various fields. Many researchers use SDN controller to manipulate and manage the Wi-Fi traffic, routing, and roaming[1][2][3]. For example Yap et al. deployed the OpenRoad project in Stanford University to collect the field trial data for seamless Wi-Fi roaming[4][5]. They also further investigate how to facilitate all wireless bandwidth within android cellphone[6]. Monin et al. also provided an architecture to implement openflow controller with Wi-Fi for seamless roaming challenge[7]. In order to coordinate with different kind of AP, there are such distinguish framework which try to define a unified control interface especially for enterprise AP[8][9]. Amount of work focus on integrate Wi-Fi with cellular network[10]. WASP paper promote a solution to separate the control plane of wireless AP to 3G network[11]. Ding et al researched how to offload the cellular traffic to Wi-Fi network for cost efficiency with a SDN controller[12]. Lee et al implemented mobile SDN extension framework

to enhance WLAN visualization, QoS and energy efficiency scenarios on Android platform[13].

V. CONCLUSIONS

This paper initiate a study to collaborate the SDN controller and wireless distribution system to optimize per flow wireless traffic with multiple wireless interfaces. In particular, we designed the system to separate wireless control plane by one interface for dedicated, non-competitive communication channel to avoid interference from other busy data flows. Channel allocation by information which comes from each wireless AP could help throughput utilization for entire wireless system. The simulation result shows that assign two non-interference channels could effectively enhance the throughput performance compared to a wireless system without channel assignment. Compared to traditional repeater, WDS and WMM network topology, this system could provide per traffic flow assignment and have capability to bridge nodes with independent, no mutual interference channels.

In the future, we will further to discover the following problems

- Load balance with optimization channel bandwidth: In practical, the wireless distribution system is assembled by different kind of access points. Some nodes have multiple interfaces but some nodes may have only one interface. We want to develop an algorithm to find the best bridge methodology between these diversity nodes. For example, we could assign different control channel between different devices. Also we want to set a performance metric to measure the flows performance for combination of single and multiple interfaces access points.
- Optimize wireless roaming: Seamless wireless roaming between access points is always a demanding feature from users especially for devices with multiple interfaces. We want to develop a seamless bridge methodology for wireless system to memorize the states and sync with all access points. If users want to traverse to access points which dwells in the channel not currently be used, we want the wireless distribution system could alert the users before roaming.
- Prototype implement: We want to implement this SDN controller in Linux machines with multiple wireless cards or smartphone with multiple wireless interfaces to acquire the real environment parameters for further research.

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Yu-Ju Lee received his B.S. degree in electrical engineering from National Chung Cheng University, Chaiyi, Taiwan, in 2005 and M.S. degree in electrical engineering from University of Southern California, Los Angeles, CA, USA, in 2010. He is currently working toward his Ph.D. degree in computer science at University of Colorado Boulder, Boulder, CO, USA. Before joined CU Boulder, he worked as a system architecture engineer and had several patents in Wi-Fi, Bluetooth and embedded system.

His research interests are in applying machine learning and deep learning to enhance system performance, embedded system and networking design and analysis, and Multi-User MIMO (MU-MIMO) in Wi-Fi and multi-radios coexistence system.