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Indian Institute of Technology Hyderabad

LOAD AWARE HAND-OFFS IN SOFTWARE DEFINED WLANS

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Outline

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- Proposed Work
  - Load Aware Hand-off Algorithm for Software Defined WLANs
- Testbed Setup
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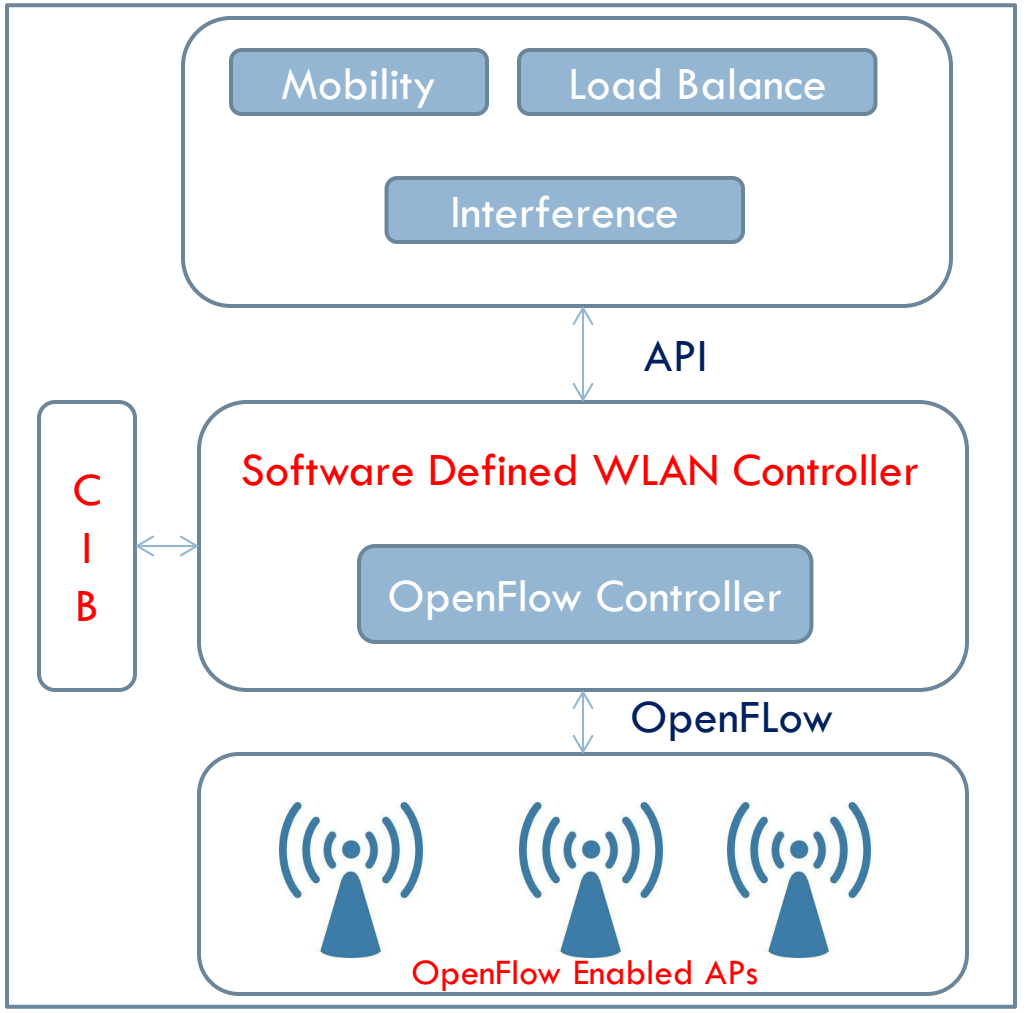
Introduction

- Software Defined WLANs
  - APs are integrated with *Open vSwitch*
  - APs are integrated with handling

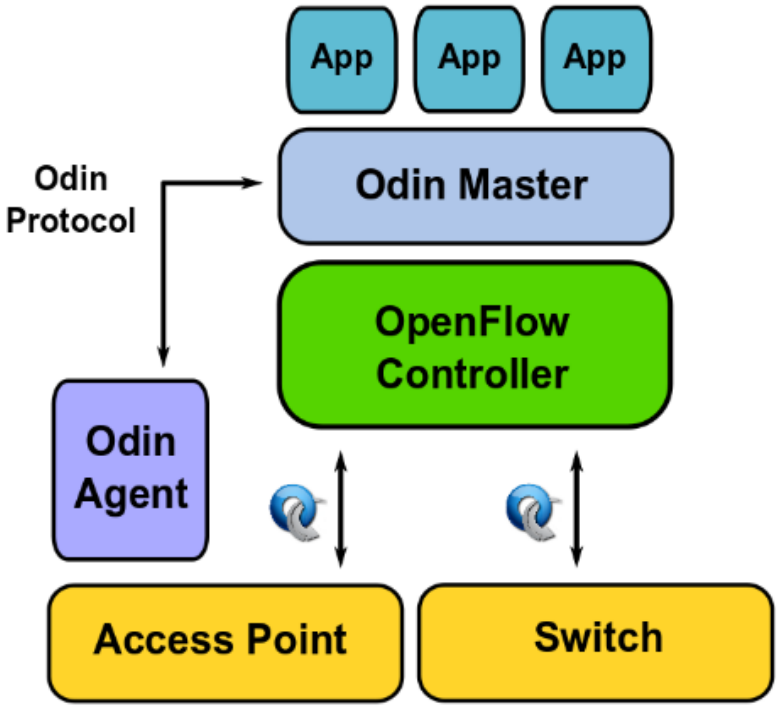
  User/kernel space (e.g Click) software for handling Lower and Upper MAC functions
- WLAN control algorithms runs on top of *OpenFlow* controller
  - Example: Mobility , Hand-Off, Interference etc. algorithms
- Central Information Base
  - Maintains AP related information like AP load, operating channel, clients connected to each AP etc.
  - Neighbors of each AP
  - Client Specific attributes MAC, IP, traffic details



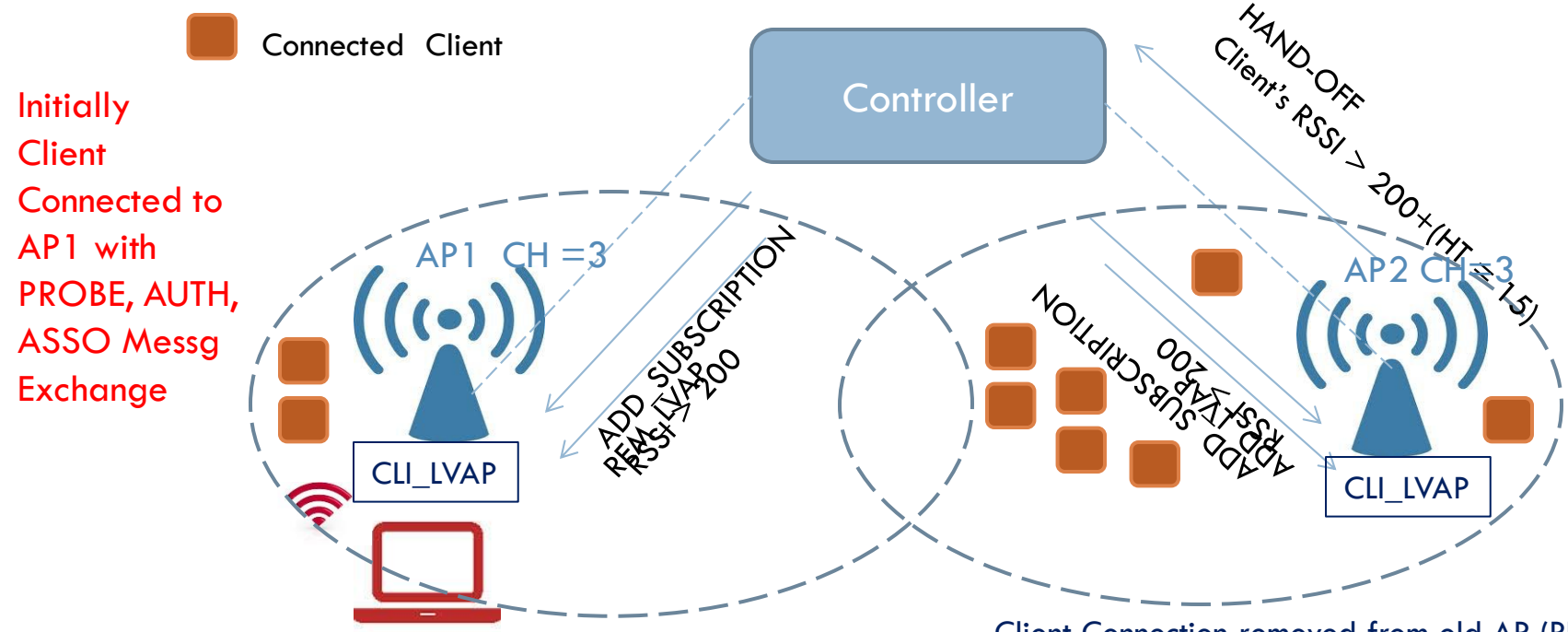
Architecture of Software Defined WLAN System

Existing Work

- ODIN is a programmable WLAN Arch.
  - It provided open source framework for developing SD WLAN algorithms
  - It simplified client association mechanism with Virtual Access Point (VAP) concept
    - Each connected client associated with LVAP(unique BSSID) on particular AP
    - It reduced Hand-off delays with *ADD LVAP* and *REM LVAP* messages
- But, it did not consider issues related to RSSI based clients association or load balance in WLANs with static clients
- A major limitation: all neighboring APs of WLAN need to operate on same channel



ODIN LVAP mechanism for Hand-Offs



Major issues :

Lot of Interfernce

Each AP depends on same Subscription for Hand-Off decision

No Network awareness for Hand-off decision

Load imbalance can result into network due to RSSI based decisions

Client Connection removed from old AP (REM_LVAP) and Moved to new AP with (ADD-LVAP)

Client need not send any RE-ASSOC MSGs

So it reduce Hand-Off delay

But major limitation: both AP should operate on Same Channel

Proposed Work

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- ODIN architecture extended to support load-aware hand-offs in multi-channel WLANs
  - Hand-off decisions are defined based on RSSI and AP traffic loads
  - Fewer messages between APs and the Controller to gather required network information
  - IEEE *Channel Switch Announcement* (CSA) messages are integrated to the extended architecture to support APs operating on different channels

Load of an AP

- Load of an each AP is defined as Traffic Intensity (TI) [1].
- TI measures utilization of channel resources in a range from 0 to 1, where 0 indicates channel is idle and 1 indicates channel is fully occupied.
  - It's a lower bound on actual busyness as it does not consider failed packet transmissions and IFS times in between packet transmissions
- TI is defined as the amount of time the AP is busy (AP-BUSYTIME) with transmission or reception of *N* frames in a given time period *T* (in seconds).
- Its calculation includes all Data, Management, and Control MAC frames
- *For each frame* $d_i = \frac{frame\ length}{PHY\ data\ rate}$
- $TI(t) = \frac{\sum_{i=1}^{N} d_i}{T}$
- TI(t) is sent to the controller in PUBLISH_AP_LOAD messages
- Controller updates for each AP the load as CTI(t)

  $CTI(t) = 0.9 * TI(t) + 0.1 * CTI(t-1)$
  - We have given 90 % weightage to Current load to reflect sudden load changes at that AP

[1] B. R. Tamma, N. Baldo, B. Manoj, and R. R. Rao, "Multi-channelwireless traffic sensing and characterization for cognitive networking," in Communications, 2009. ICC'09. IEEE International Conference on.IEEE, 2009, pp. 1–5.

Network Awareness Messages

- PUBLISH-AP-LOAD message is for periodically sending AP load to the SDN controller
- PUBLISH-CLIENT-LOAD message is for reporting each client individual load
- PER-AP-HANDOFF-SUBSCRIPTION message is for changing AP initial subscription according to its new load

Load Aware Hand-off Algorithm

- **loop**
- Updates RSSI Threshold value to be matched against APs' load level
- When it receives HAND-OFF request from an Competing AP
- **if** $((Load_{connectedAP} - Load_{competingAP}) > HT_{LOAD})$ *and*

  $(RSSI_{connectedAP} < (RSSI_{competingAP} + HT_{RSSI1}))$ – Condition 1

  then Hand-off the client to the competing AP
- **else if** $((RSSI_{competingAP} > (RSSI_{connectedAP} + HT_{RSSI2}))$ *and*
- $(Load_{competingAP} < (Load_{connectedAP} + HT_{LOAD}))$ – Condition 2

  then Hand-off the client to the competing AP
- **else**

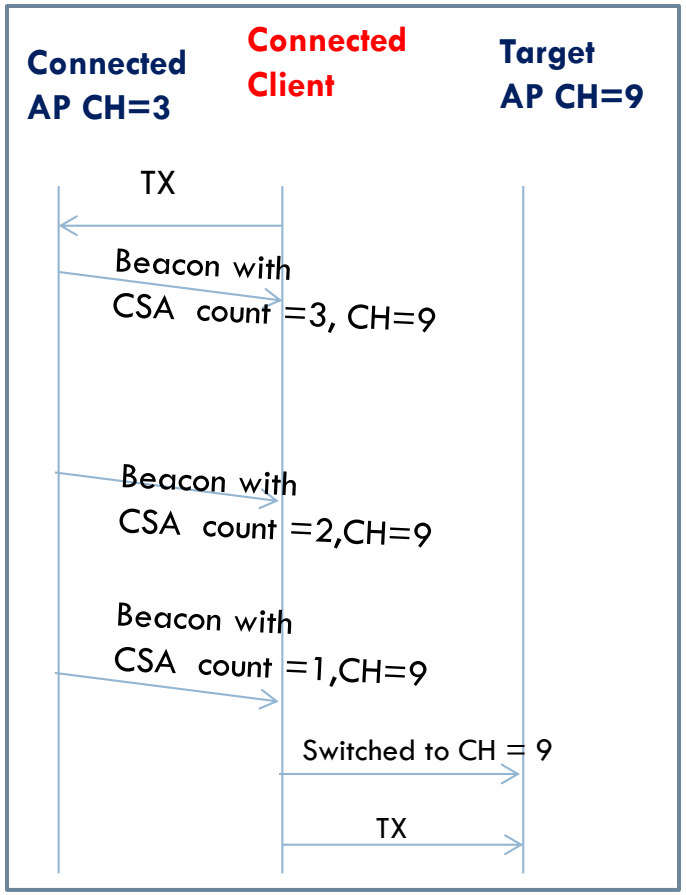
  No Hand-Off
- **end if**
- **end loop**

Load Level	RSSI Threshold
high	215
medium	200
low	185

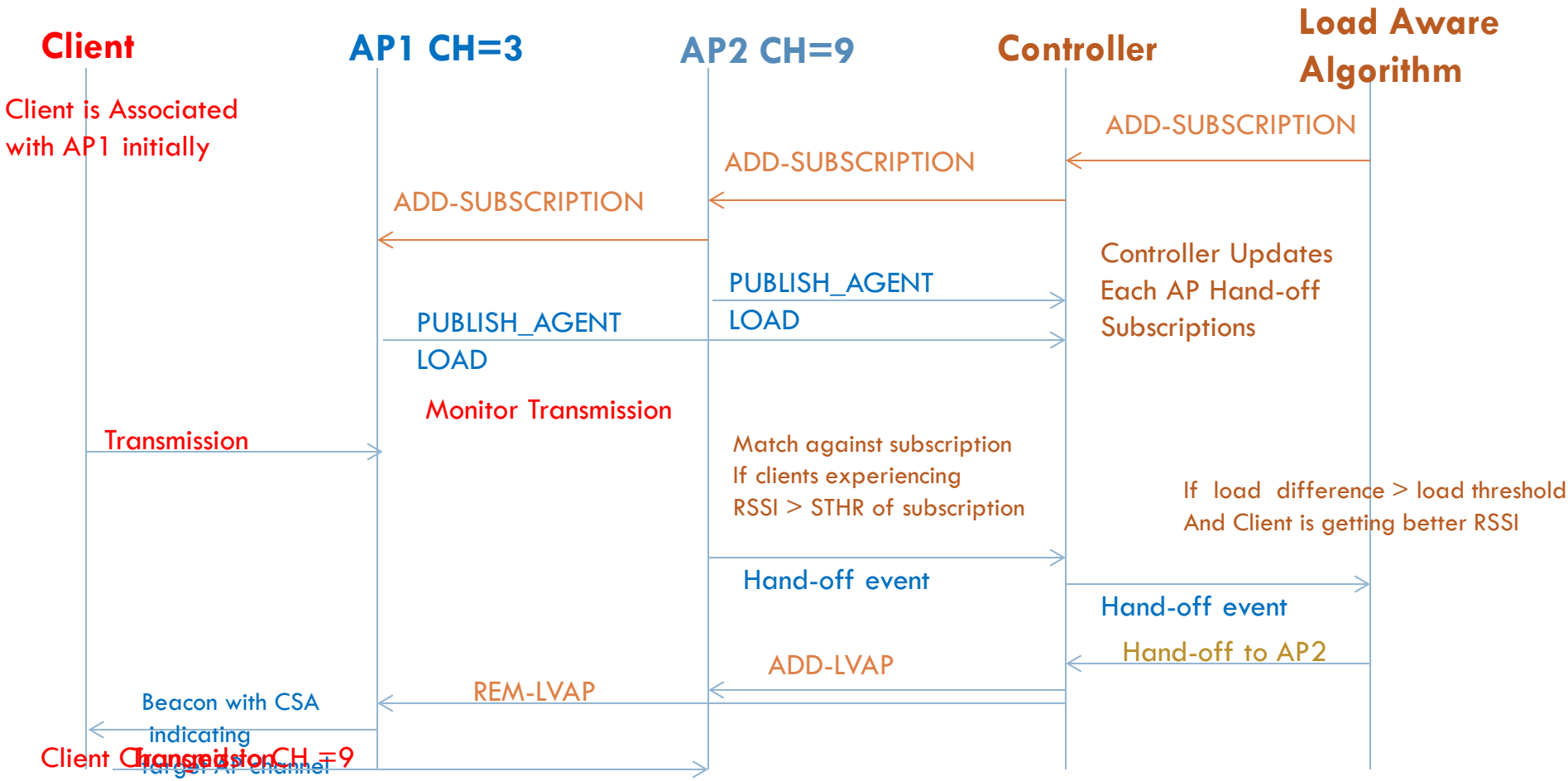
How to ensure Load-Aware Seamless Hand-off in multi-channel WLANS

- Identify max RSSI variations in environment and map each AP's RSSI threshold according to its load levels
- Before removing LVAP from Connected AP, it sends *IEEE CSA* Channel Switch Announcement message to target AP

ElementID	Length	Channel Switch Mode = 1	New Channel Number = Target AP Channel	Channel Switch Count =3

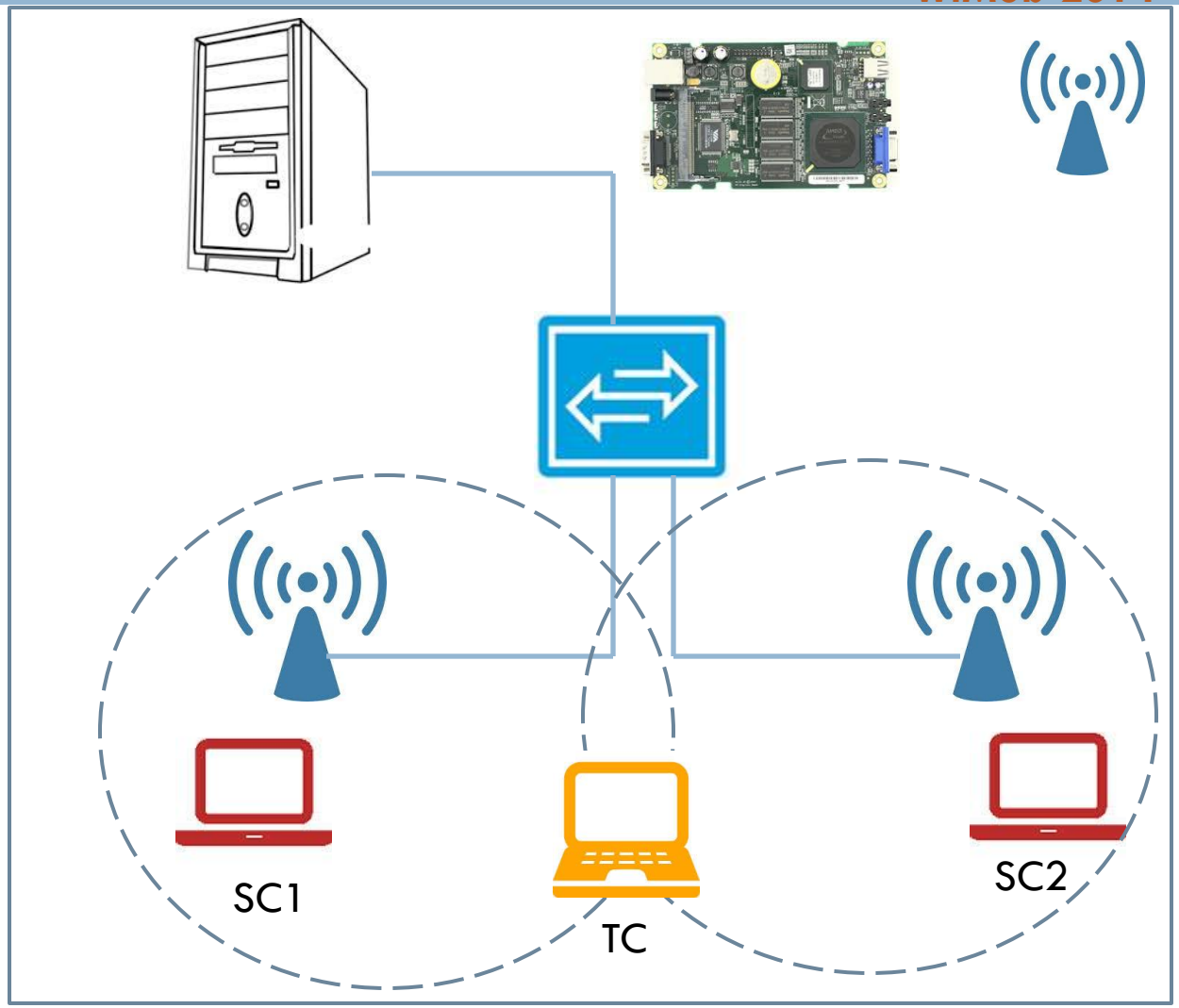


Sequence diagram of seamless load-aware hand-offs



Testbed

- A server runs TCP *iperf* server and floodlight controller based SDWLAN
- AP runs click based Agents
- Clients are configured with static IP addresses
- On Client, *iperf TCP* client is running



Testbed Setup Details

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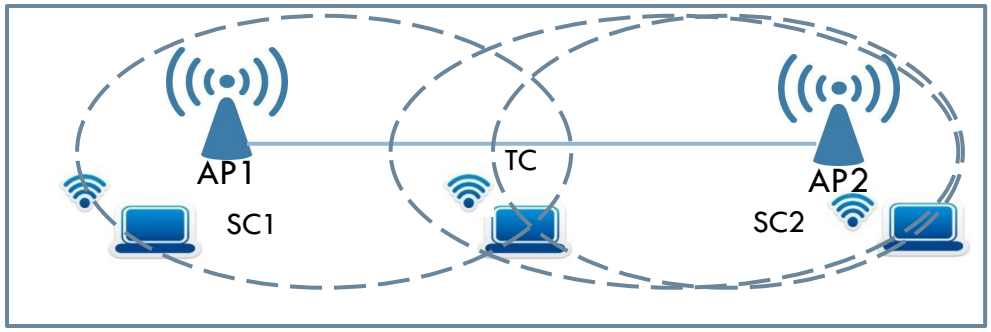
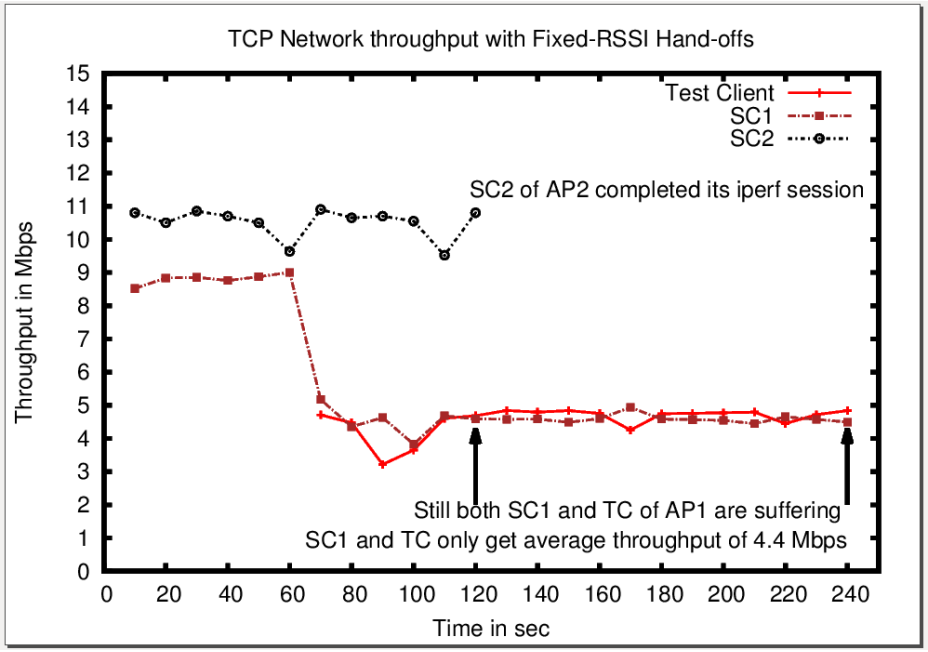
Testbed Components	Details
Number of APs	2 (Alix3d3 boards)
AP Wi-fi Cards	2 (Ath9k 802.11bgn)
APs' operating mode	802.11g
Operating System on AP	Openwrt
Other tools on AP	Click2.0.1 and Open vSwitch1.9.0
Number of Clients	3
Linux Kernel version of Clients	3.5
Controller Software	Floodlight
Configurable Parameters	**Values**
Initial STHR	185
HT_{LOAD}	30%
HT_{RSSI1} , HT_{RSSI2}	10, 15
Channels tested	3, 9 of 2.4GHz
α (Weightage to current load)	0.9
T (Periodicity of Load Reports)	1 sec

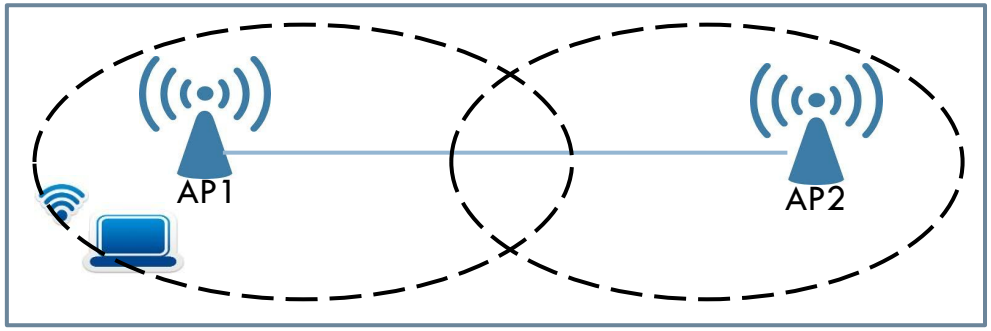
Experiment 1



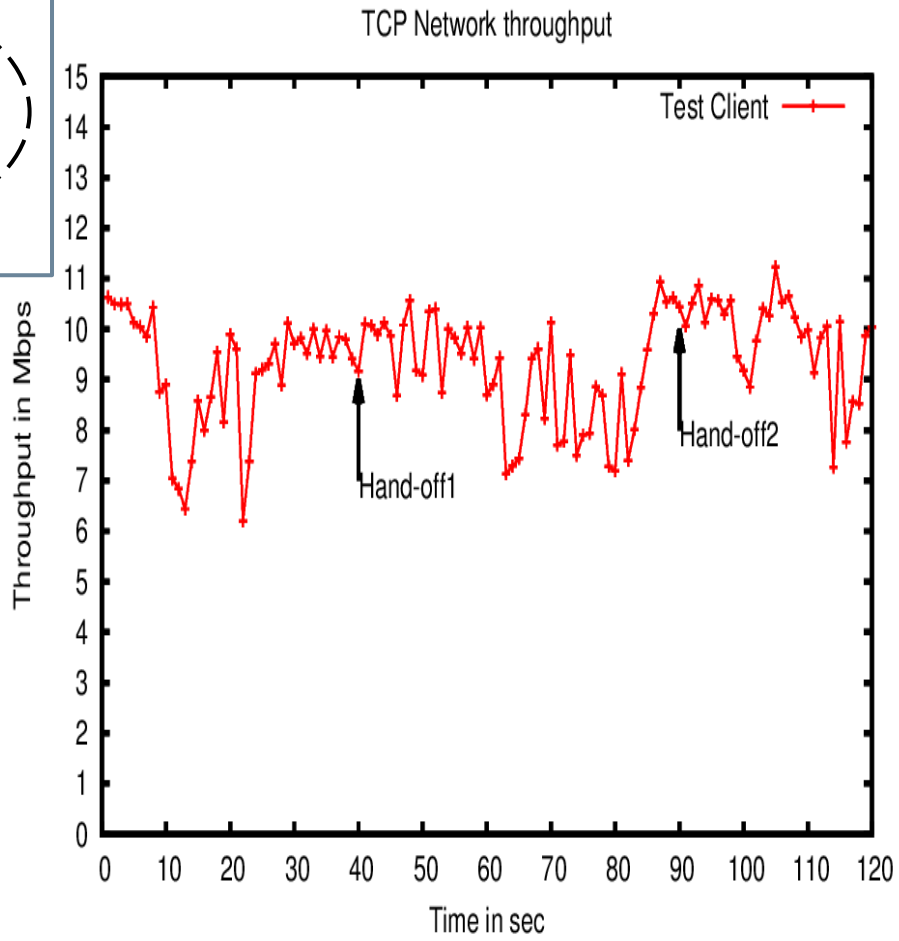


- Aim : Load balance even for static clients with hand-offs
- At *t=0*
  - SC1 with AP1 starts TCP iperf of duration = 240 sec
  - SC2 with AP2 starts TCP iperf of duration = 120 sec
    - Load of AP1 and AP2 are equal
    - SC1 and SC2 are utilizing entire Bandwidth (9 Mbps each)
- At *t=60*
  - Test Client (TC) with AP1 starts TCP iperf of duration = 180sec
    - Now with AP1 network bandwidth sharing equally between SC1 and TC(Each is getting 4.5 Mbps)
    - Still load of AP1 and AP2 are equal
- At *t=120*
  - SC2 with AP2 completed TCP iperf session.
  - Now Load of AP1 and AP2 are become High and Low respectively
  - By detecting this load imbalance the load aware hand-off algorithm handed-off TC to AP2
- From *t=120 to t=240*
  - SC1 with AP1 is utilizing entire available network bandwidth of 9Mbps
  - TC with AP2 also is utilizing entire available network bandwidth of 9Mbps

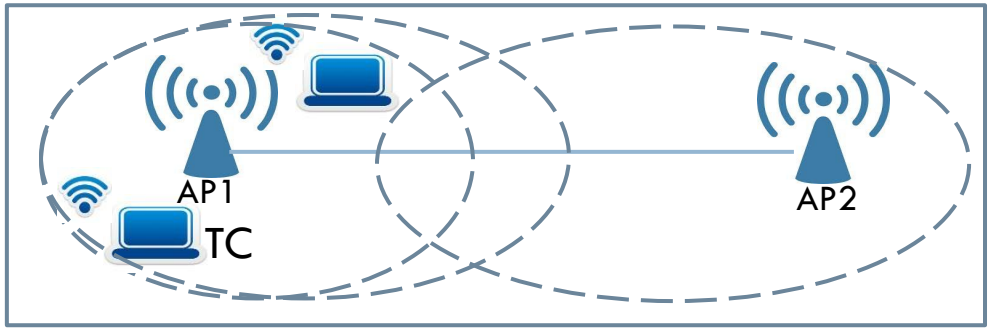
Experiment 2



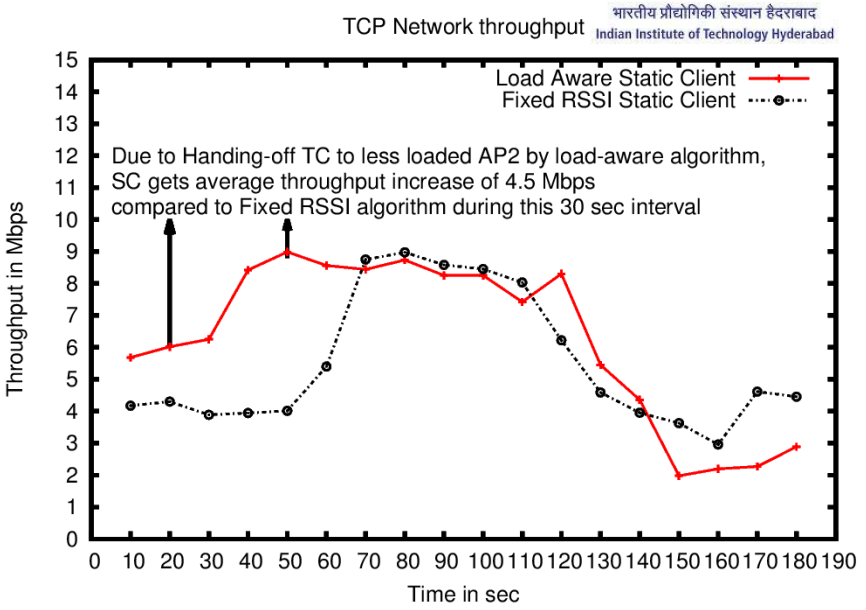
- Aim: Seamless Hand-off even in multi channel operating WLAN
- From 0 to 60 Sec Client is moving from AP1 to AP2
- At t=40 Sec Approximately Test Client Handed-off
  - No Drop in throughput
- From 60 to 120 Sec Client is moving from AP2 to AP1
- At t=90 Sec Approximately Test Client Handed-off
  - No Drop in throughput

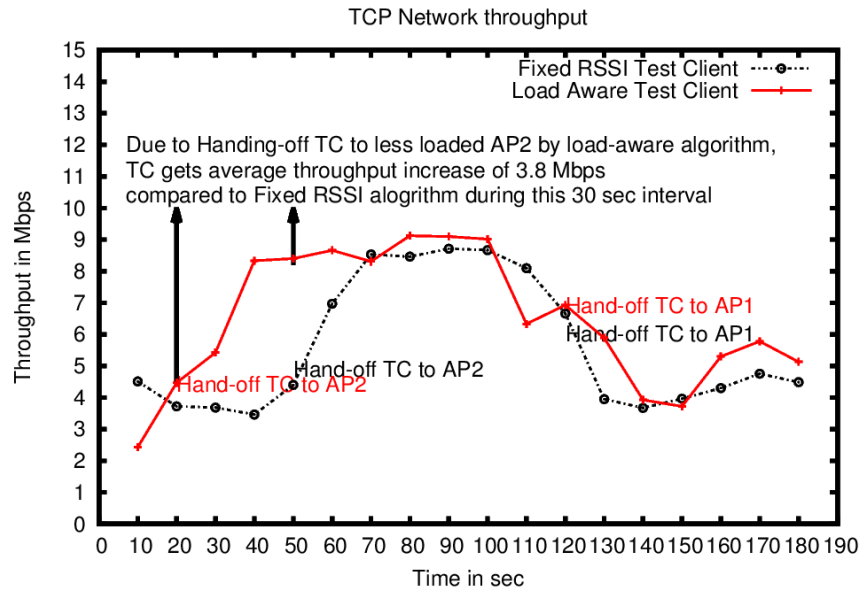


Experiment 3



- Aim: According load changes do Hand-off
- At t=0 SC,TC are connected with AP1 started iperf TCP for 180sec
  - AP1 is Highly loaded compared to AP2
  - AP2 coverage is set to High by load aware hand-off algorithm
- At t>0 TC started moving towards AP2
  - At t=20 TC Handed-off by load aware hand-off algorithm
  - Early Hand-off results improved throughput to SC(4.5Mbps) and TC(3.8Mbps) between 20 sec to 50sec interval
  - Load-aware algorithm adjusts again STHR value to be matched against AP1,AP2 according to their load
- After t=90 sec TC moving backwards to AP1
  - As AP1,AP2 are now equally loaded
  - At t=133(approximately) TC again handed-off to AP1
  - Now both are equally loaded so hand-off occurs based on better RSSI





Conclusions and Future Work

- From Experiment 1: we can observe how static clients also can utilized available network bandwidth and get benefited from the load aware hand-off algorithm
- In Experiment 2 we showed how SD WLANs can deployed in multi-channel environment for controlling interference and still achieving seamless hand-offs
- In Experiment 3: we showed that, during mobility of clients, how to ensure good RSSI to clients in addition to load aware decisions without any ping-pong effects
- We tested these results in a small scale testbed, as part of future work we plan to test it on an enterprise WLAN testbed
- We are implementing SDN LTE network framework in NS-3 and testing network aware load balance application

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Thank You

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