ViFi:

Virtualizing WLAN using Commodity Hardware

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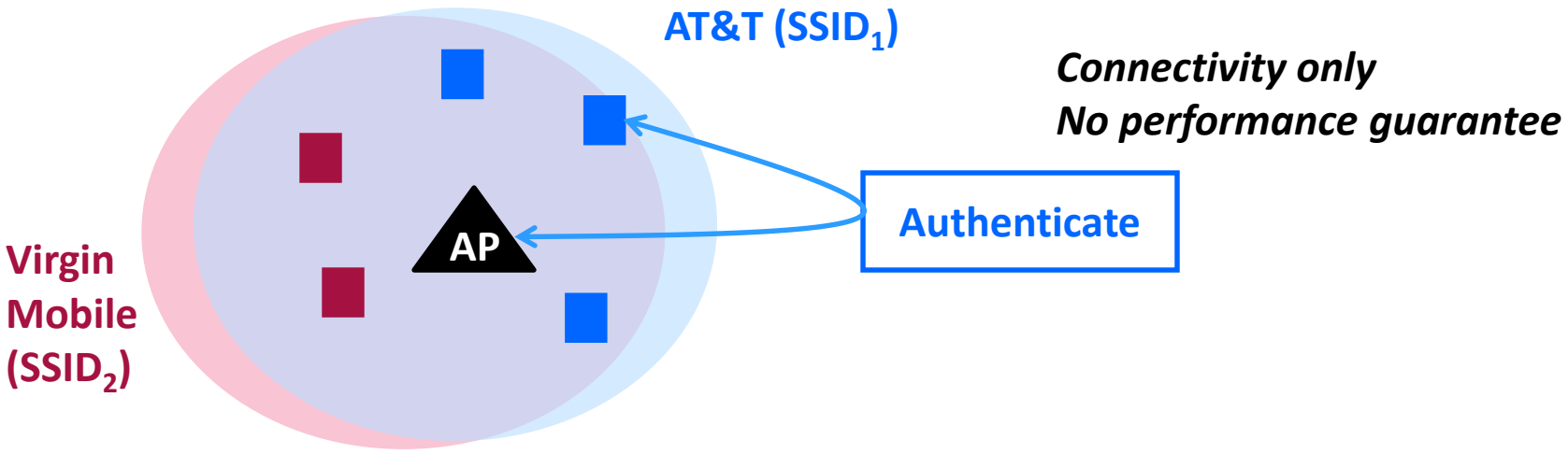
September 11, 2014

Motivation

- **WiFi infrastructure is ubiquitous, increasingly used for data offloading**
- **Need for multiple operators to share this infrastructure**
- **Enable Software Defined Networking for WiFi**



- **Goal: to provide more control (beyond authentication) to *virtual* network operators on *virtual* WiFi networks (traffic isolation)**

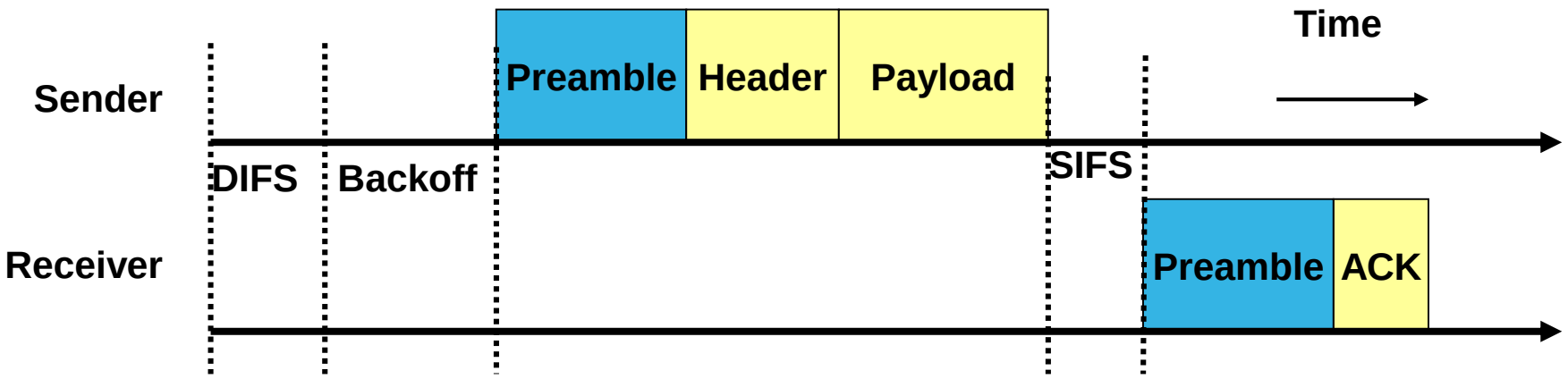
What to Virtualize?

- **Virtualization through resource sharing in wireless networks**

- **Resources in wireless networks**
  - Backhaul network -- capacity to and from the core network
  - Processing -- compute and memory for packet processing inside the access points (APs)
  - ***Wireless medium (air or spectrum)***
    - Different frequency bands (802.11 channels) for different virtual operators
    - ***Single channel used by multiple operators***

DCF Access Mode for 802.11 MAC

- **Deployed 802.11 use Distributed Coordination Function (DCF)**
  - Exponential back-off based CSMA/CA
  - CW: Contention Window
  - Back-off timer randomly chosen from [0, CW-1]
  - Station doubles CW from CWmin to CWmax after sensing busy channel



DIFS: Distributed Inter-Frame Space
SIFS: Short Inter-Frame Space

802.11 Quality of Service Enhancements

- **802.11e Enhanced Distributed Channel Access (EDCA) mechanism**
  - Transmission Opportunity(TXOP)
    maximum time duration during which a station has the right to initiate transmissions without contention
  - Allows varying CWmin
  - Allows varying TXOP
- **802.11n**
  - Frame aggregation
    Each station can set its maximum aggregation limit (equivalent to TXOP)
- **The AP can advertise these values for stations in Beacon frames**
  - Allows one set of (CWmin,TXOP) parameters for each SSID

Practical DCF controls in 802.11

- **Optimal CWmin to maximize system throughput**

$$CWmin_{opt} = sqrt[(E[P]+100)/9] * (n-1)$$

  - All n stations transmit with the same data rate (54 Mbps)
  - Same MAC payload size P bytes
  - *CWmin can only be power of 2*

- **$Tput_1 / Tput_2 = CWmin_2/CWmin_1$** ***Coarse-grained***
  - Inverse proportion holds for $CWmin_i >= 8$

- **$Tput_1 / Tput_2 = TXOP_1/TXOP_2$** ***Fine-grained***
  - Proportional relation holds linearly only when $Tput_1 / Tput_2$ in range [1,2]

Virtual WiFi (ViFi) Concepts

- **Service Flow: unidirectional traffic between an AP and a user station**

- **Slice: a group of service flows**

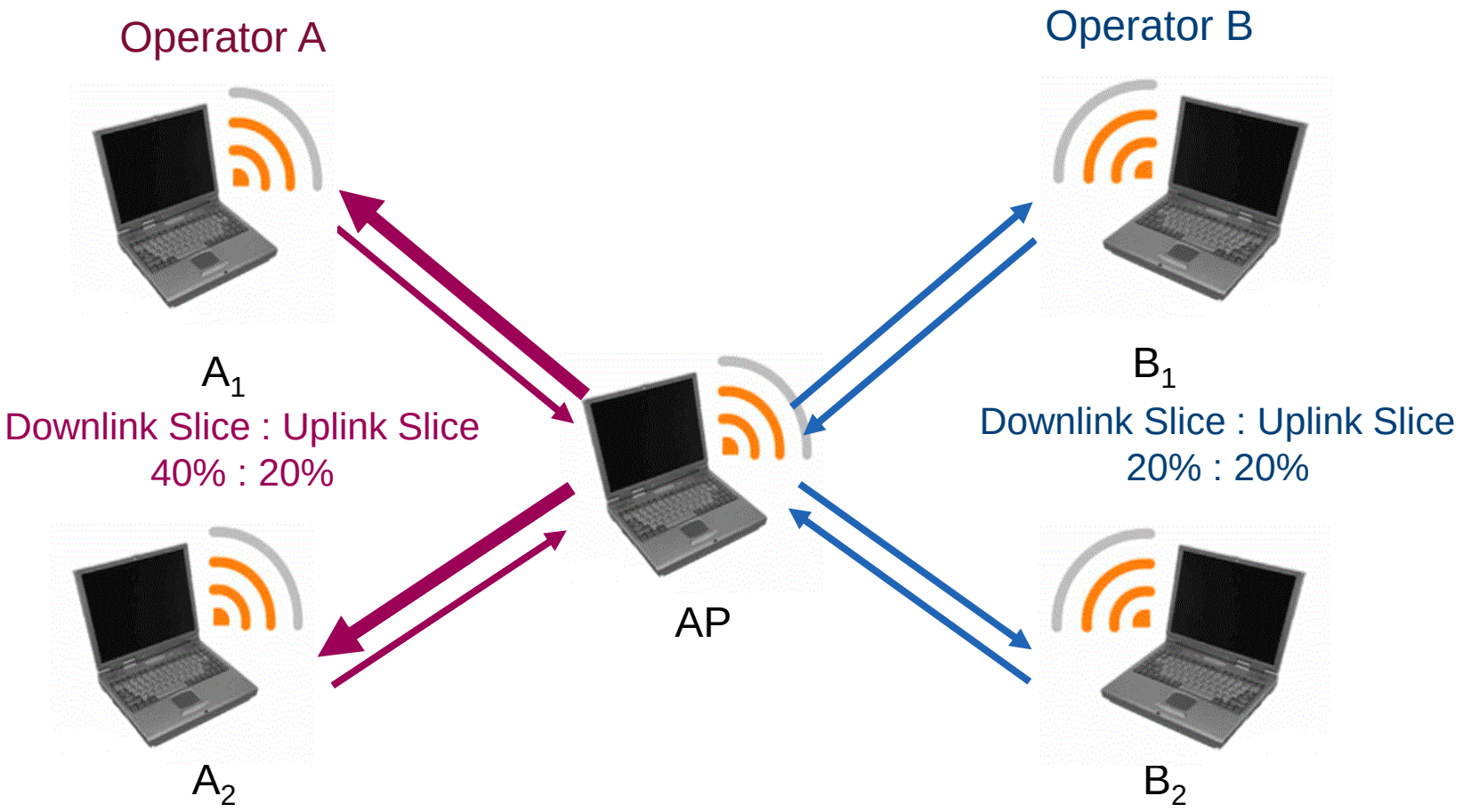
- **Service Level Agreement (SLA) between virtual operators and ViFi infrastructure providers**
  - Per-slice air-time guarantees: % total air-time
  - Per-station: Either air-time share or throughput share

- **Maximize overall system throughput using $CWmin_{opt}$**

  $CWmin_{opt} = sqrt[(E[P]+100)/9] * (\mathbf{n}-1)$

  - Compute system size by mapping each physical station to multiple **virtual stations**
  - Example: An AP serves uplink flows from two stations: A_1 (60%) and A_2 (40%)
    - Station A_1 = 3 virtual stations
    - Station A_2 = 2 virtual stations

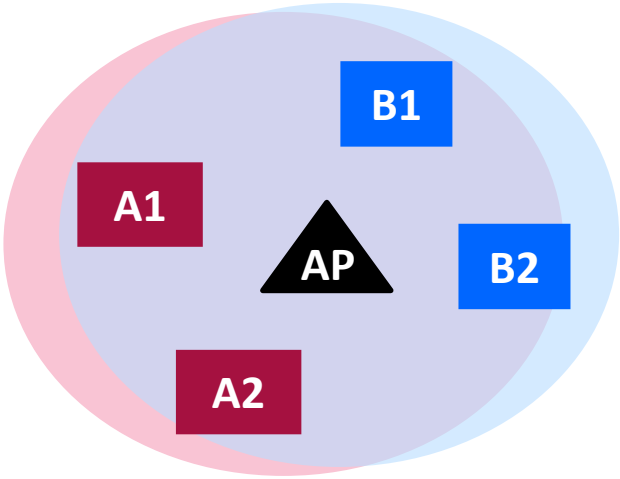
Testbed Experiments



- Cisco Aironet 802.11a/b/g adapter (Atheros) in 2.4 GHz g mode
- MadWiFi-0.9.4 device driver
- Iperf UDP traffic with MAC frame size 1500B
- Single data rate of 54 Mbps

DCF Configuration

- **Compute system size**
  - A1=A2=B1=B2= 1 virtual station
  - AP = 6 virtual stations (all downlink flows)
  - Total of n=10 virtual stations

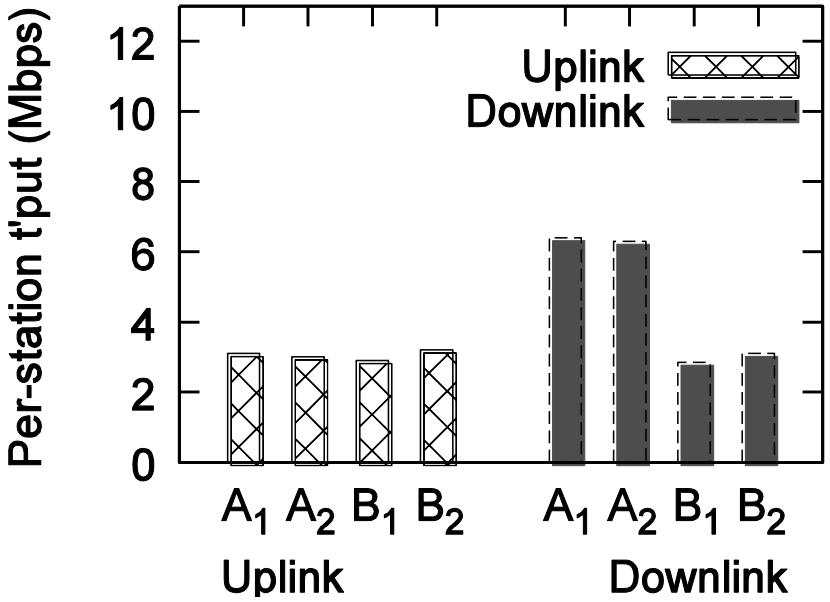


- **$CWmin_{opt} = 54$, ($2^5 < 54 < 2^6$) → $CW_{lo} = 32$**

- **Uplink configuration**
  - $CWmin_{sta} = \max(8, CW_{lo}) = 32$
  - $TXOP_{sta}$ = 256 usec (802.11g) or **zero**

- **Downlink configuration**
  - 6 virtual stations = 4 * 1.5
  - $CWmin_{ap} = CW_{sta} / 4 = 32/4 = 8$ — *Coarse-grained*
  - $TXOP_{ap}$ = 256 * 1.5 usec = 384 usec — *Fine-grained*

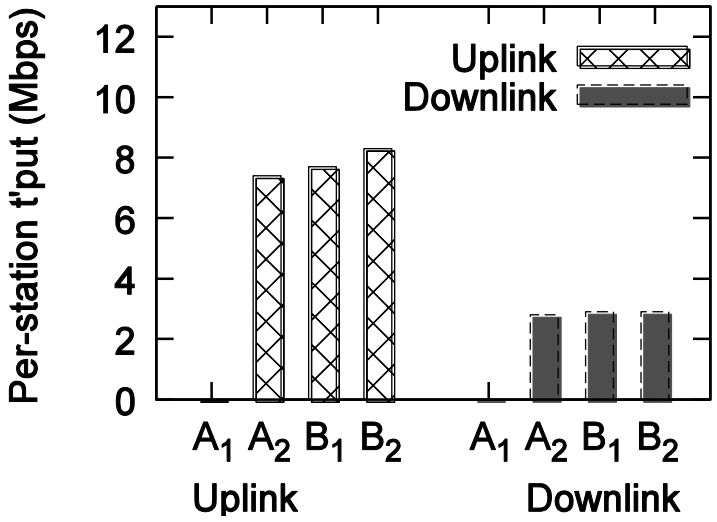
ViFi Honors SLA in Terms of Air-time Share



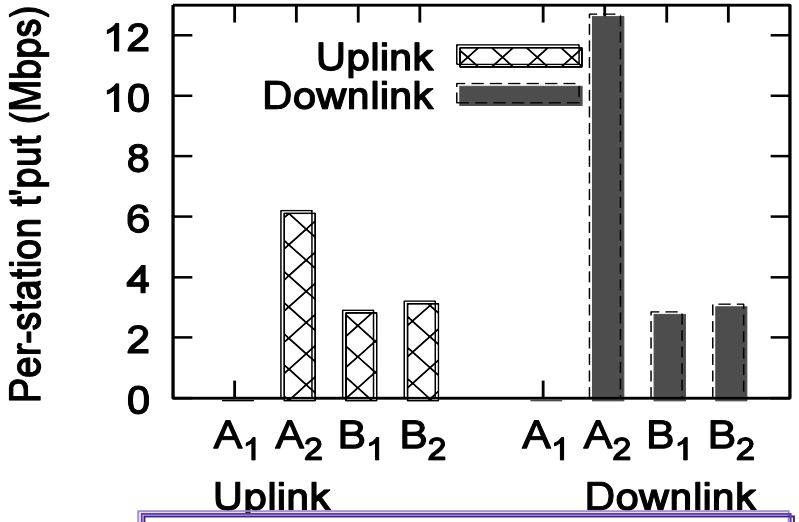
ViFi
CW_{ap}=8, $TXOP_{ap}$= 384 usec
CW_{sta}=32, $TXOP_{sta}$=0

ViFi Honors SLA in Terms of Traffic Isolation

- A1 shuts down or moves away from the AP, with same SLA
- A2 = 2 virtual stations, B1=B2= 1 virtual station
- AP: Still 6 virtual stations, split as 4 (A2) + 1 (B1) + 1 (B2)
- Total of n=10 virtual stations → same CWopt
- $CW_{A2} = CW_{sta}/2 = 32/2 = 16$



No ViFi:
CW_{ap}=16, $TXOP_{ap}$=0
CW_{sta}=16, $TXOP_{sta}$=0



ViFi:
CW_{ap}=8, $TXOP_{ap}$=384usec
CW_{sta_B}=32, $TXOP_{sta\_B}$=0
CW_{sta_A2} = 16, $TXOP_{sta\_A2}$=0

Concluding Remarks

- **ViFi is a practical solution to virtualize WLAN for sharing across multiple operators**

- **ViFi provides mechanism for service differentiation and traffic isolation between virtual operators**

- **Ongoing and future work:**
  - SLA in terms of throughput share
  - Dynamic ViFi : monitor and predict the changes in group size
  - Multi-AP setting: interference reduces overall system throughput but not affect SLA
  - Mobility of user stations: translates to change in data rate

Thanks!