Inhomogeneous Wireless Network Load Distribution

Kuang-Hui Chi*   Meng-Hsuan Chiang
Institute of Electrical Engineering
National Yunlin University of Science and Technology
TAIWAN
chikh@yuntech.edu.tw

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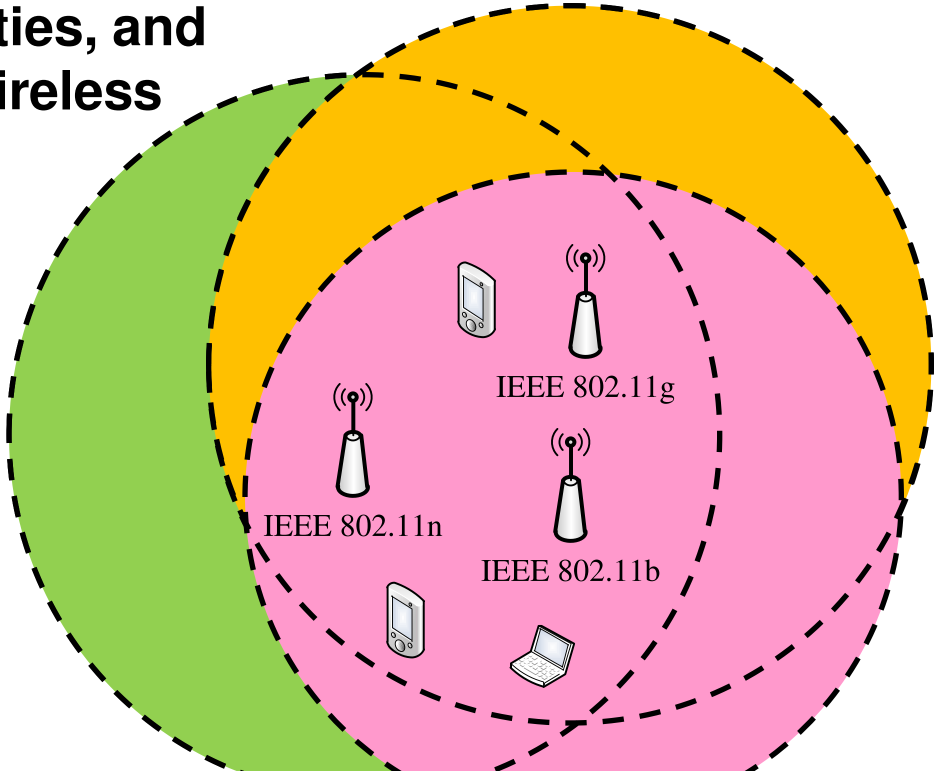
Background (1/3)

- Observations
  - Network inhomogeneity appears common as devices of different generations/capabilities were phased in over time
  - Households may deploy IEEE 802.11n access points (APs) with joint use of earlier WiFi apparatus
  - Varying coverages, capabilities, and service rates affect how a wireless station selects which AP to associate with
    ⇨ load imbalance
  - Traffic may concentrate on less capable APs unevenly



Background (2/3)

- **Objectives**
  - **Distribute traffic among inhomogeneous APs for users**
  - **Implementation over Android, add-on software, an APP**
- **Operation synopsis**
  - **APs of different generations deployed in an area where a server is introduced to collect user's grade points or other relevant information**
  - **A grading method allows for how long an Android handset used each type of AP in the past**
  - **Connection time is considered plus or minus with respect to an IEEE 802.11b AP and 802.11n AP (newest)**
    - **802.11b (slower) < 802.11g (fair) < 802.11n (faster)**

Background (3/3)

- **Operation synopsis (cont'd)**
  - Connection time is considered plus or minus with respect to an IEEE 802.11b AP and 802.11n AP (newest)
    - The longer a handset was with an IEEE 802.11b AP, the more points it gains, in favor of its eligibility to connect to an IEEE 802.11n AP later
    - The longer the handset was with an IEEE 802.11n AP, the more advantage it loses, making it less likely to use the IEEE 802.11n again in the future
  - Based on the ranking of grade points, the appropriate AP is chosen for each wireless user to camp in

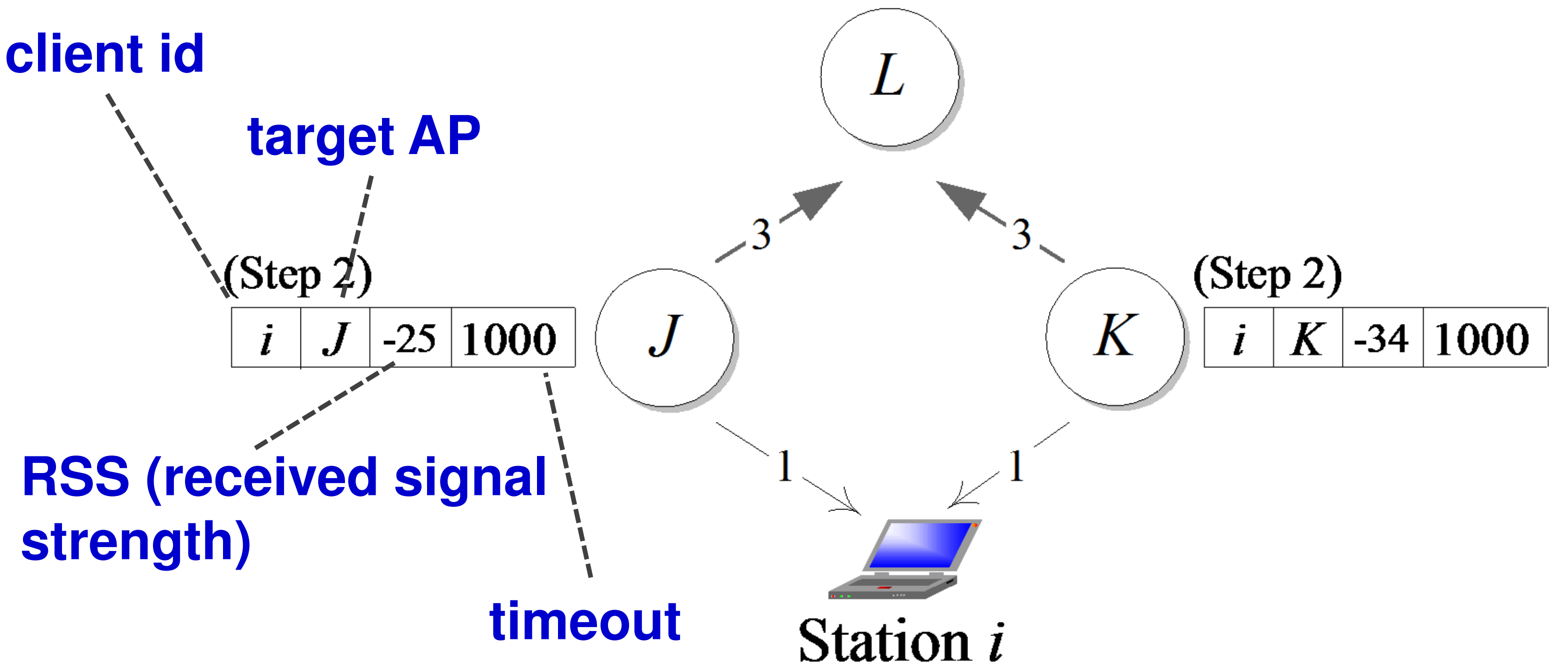
Literature Review: Summary

- State-of-the-art research did not address network inhomogeneity
  - Performance limited somehow
  - Per-AP capability not fully utilized
- Most schemes require tailoring standard protocol machinery on the AP side or client side
  - Incompatible with standard devices
  - Propreitary, interoperability?

Selection of Most Recent Work

K.-H. Chi and L.-H. Yen, “Load Distribution in Non-homogeneous Wireless Local Area Networks”, *Wireless Personal Communications*, 75(4):2569–2587, April 2014

- **Information exchange: An example**



(a) Both APs *J* and *K* send the station *i* a Probe Response (step 1), record the information in their respective association tables (step 2) and broadcast the recorded information to the LAN (step 3.) This enables association tables at different sites to accummulate same entries.

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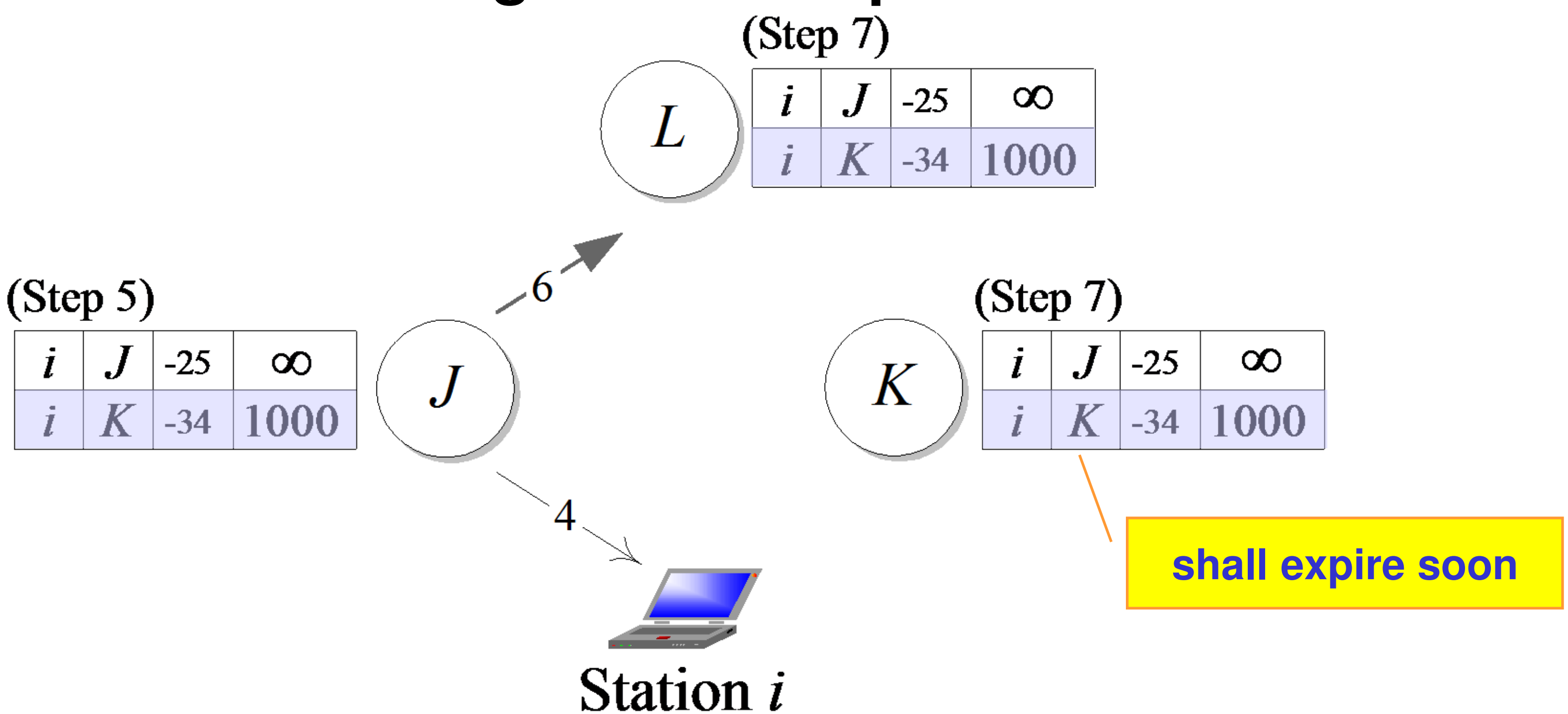
- **Information exchange: An example**



(b) AP *J* accepts and sends the station *i* an Association Response (step 4), resets the entry with index (*i*,*J*) to have infinite Expiration Time (step 5), and broadcasts the event of association to the LAN. Upon receipt, APs update the corresponding entry accordingly in their maintained tables (step 7.)

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- Suppose:
  - A new station *i* detects a set of APs in range
  - For each such AP *J*, S_J denotes the set of stations local to *J*
- Responsiveness
  - *J* might take a delay of $\sum_{j \in S_J} 1/\mu(r_{j,J})$ to serve all the potentially contending stations for a frame unit
  - μ(): function mapping RSS to nominal transmission rates
- Fusing metrics
  - Effective bandwidth for a station increases with a stronger RSS but decreases with slower responsiveness of APs, the preference for *i* associating with *J* is

$$\mu(r_{i,J})\Big(\sum_{j \in S} 1/\mu(r_{j,J})\Big)^{-1}$$

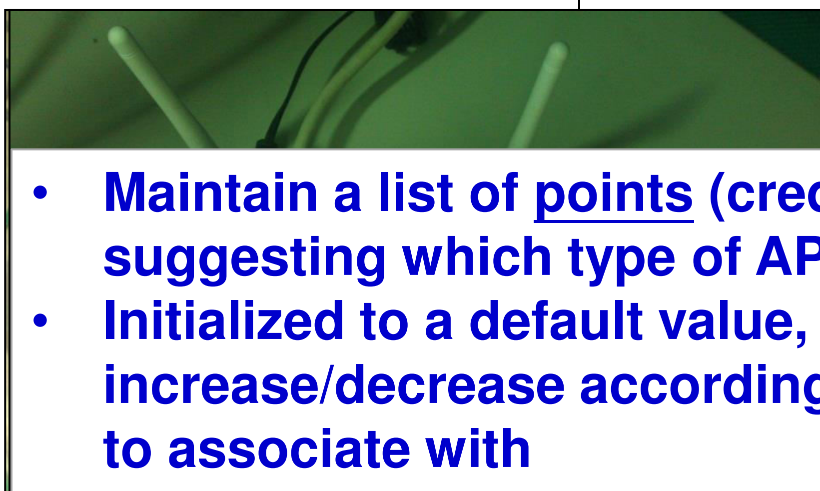
  - A best-fit AP is given by $\arg\max_X \mu(r_{i,X})\Big(\sum_{\forall j \in S_X} \frac{1}{\mu(r_{j,X})}\Big)^{-1}$

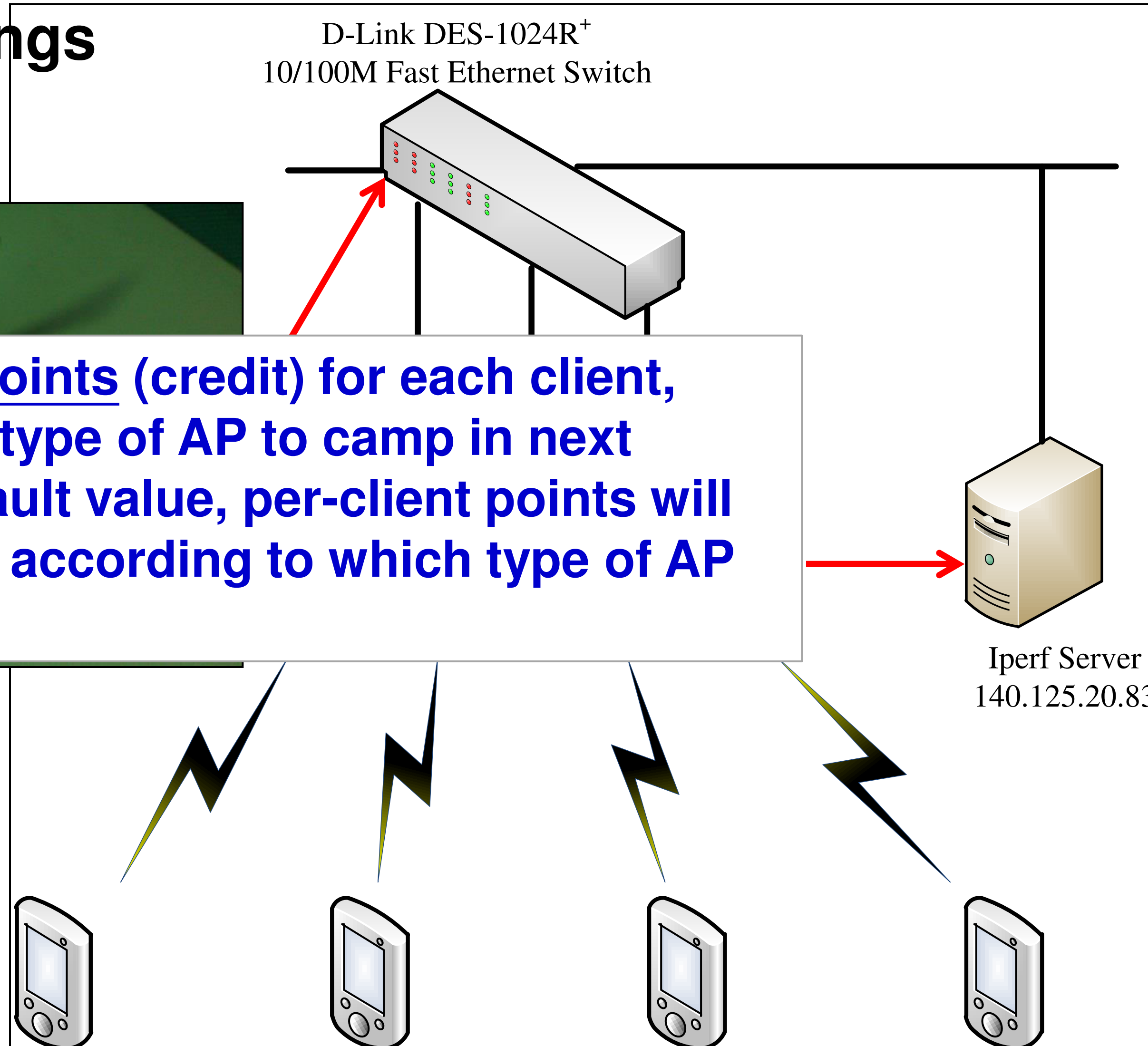
Our Approach

- centralized -

Our Approach (1/4)

- Network settings



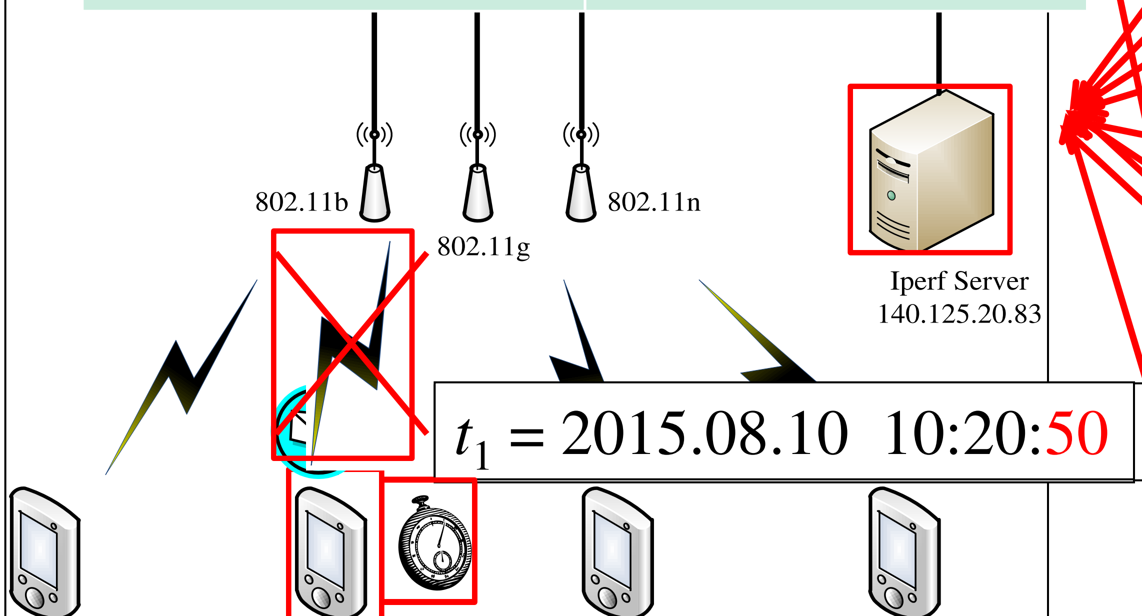


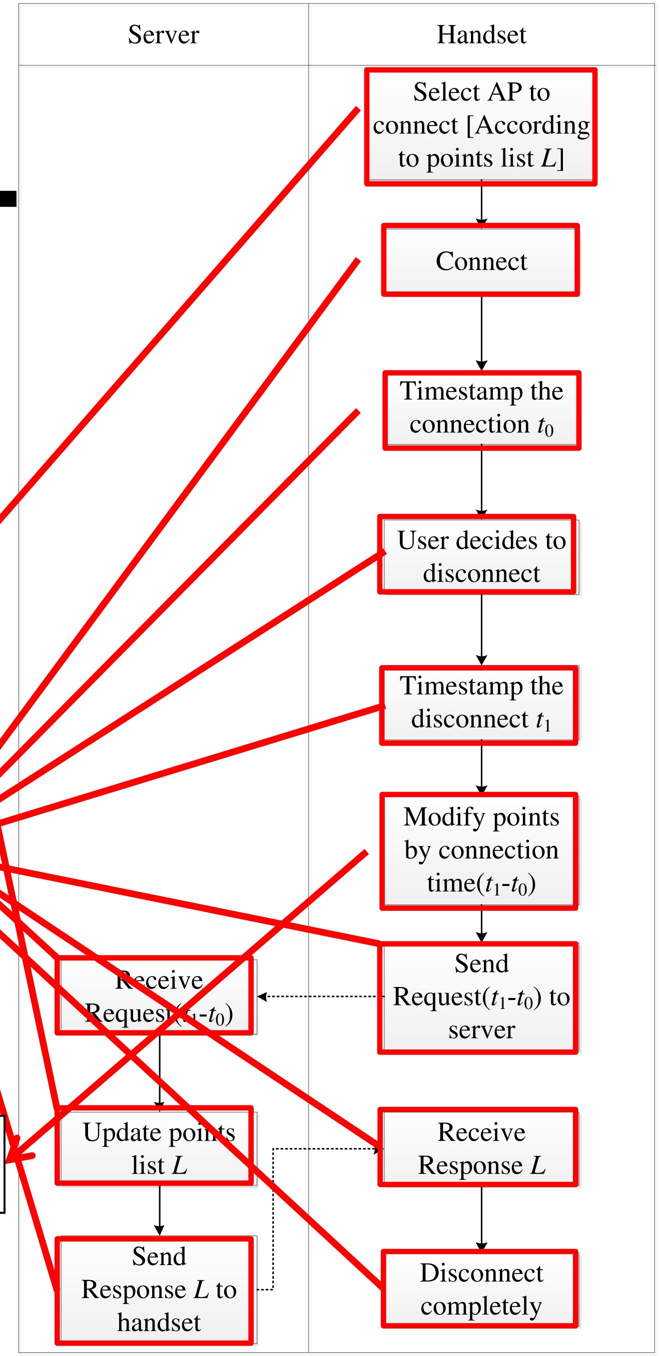
- Maintain a list of <u>points</u> (credit) for each client, suggesting which type of AP to camp in next
- Initialized to a default value, per-client points will increase/decrease according to which type of AP to associate with

Our Approach (2/4)

- **Procedural flowchart**

MAC Address	Points
90:21:55:DD:9B:E3	9980
…	
00:1F:3C:8B:14:F4	9805





Our Approach (3/4)

- **Grading policy**

AP type	802.11b	802.11g	802.11n
Update principle	Points increase with connection duration	Neutral	Points decrease with connection duration
Points adjustment	1*(connection duration) (s)	Invariant	(-1)*(connection duration) (s)

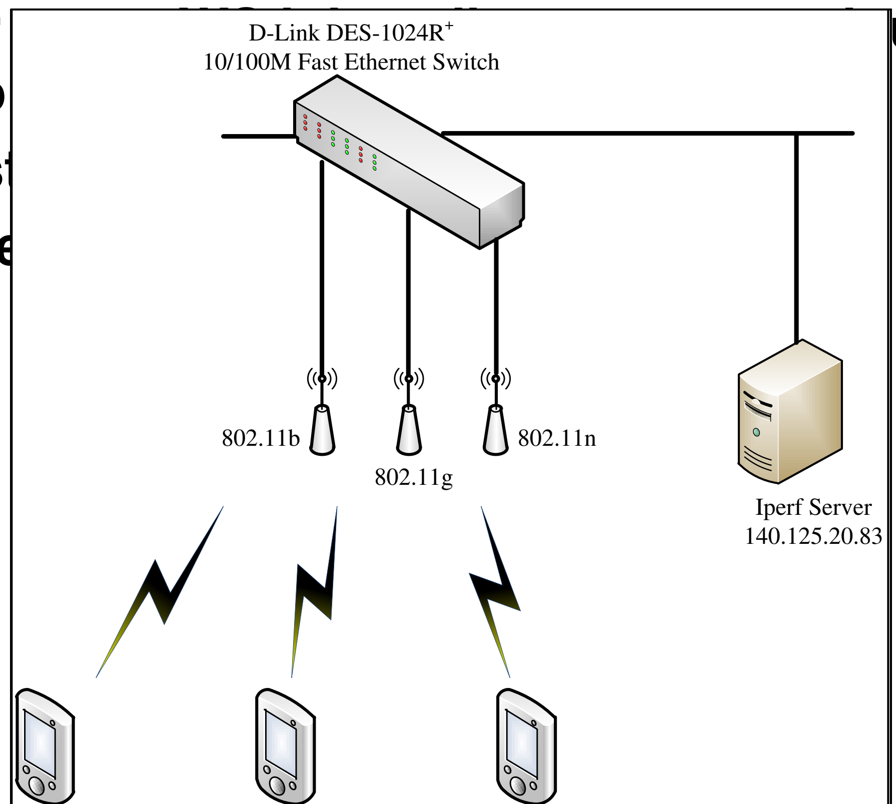
Our Approach (4/4)

90:21:55:DD:9B:E3	9961	802.11n
00:1F:3C:8A:CD:91	9950	
00:1F:3C:8B:13:10	9942	802.11g
00:1F:3C:8B:14:F4	9930	802.11b

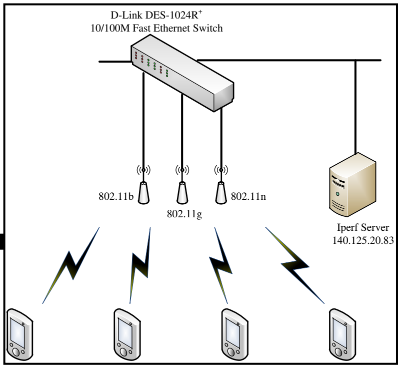
- Ranking of grade points
  - Use Iperf to test the max.
  - Bandwidth ratio of a concerned AP to all the APs (total available bandwidth)
    - 802.11n: 31.5 Mbps; 31.5/56.6 = 0.55
    - 802.11g: 19.3 Mbps; 19.3/56.6 = 0.34
    - 802.11b: 5.8 Mbps; 5.8/56.6 = 0.10
  - Such ratios multiplied by the total number of wireless stations (WSs) give a moderate share of stations to be accommodated by each AP (*room*), with preference 802.11n > 802.11g > 802.11b
    - E.g. 31.5 / 56.6 * 4 = 2.26 (802.11n)
    - Rounded to the nearest integer >= 1
    - Handset with highest point associates to the 802.11n AP, 2nd highest to 802.11n or 802.11g and so forth, depending on the room offered by each AP

Experiments (1/3)

- Scenario
  - Wireless stations join one by one (up to 4), at time 0, 10, 25, and 45
    - All the APs in radio range
  - Whenever … us WSs and re-start co…
  - 4 WSs firs…
  - Investigate…



Experiments (2/3)



- **WS 1 connected to IEEE 802.11n AP**

WS 1	90:21:55:DD:9B:E3 10000	802.11n

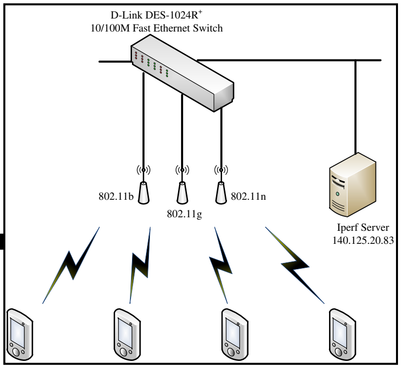
- **After 10s, WS 2 joins, disconnect WS 1 and re-start WSs 1's connection**

WS 2	00:1F:3C:8A:CD:91	10000	802.11n
WS 1	90:21:55:DD:9B:E3	9990	802.11g

- **After 15s, WS 3 joins, disconnect WSs 1 and 2, and let both WSs re-start connections**

WS 3	00:1F:3C:8B:13:10	10000	802.11n
WS 1	90:21:55:DD:9B:E3	9990	802.11n
WS 2	00:1F:3C:8A:CD:91	9985	802.11g

Experiments (3/3)



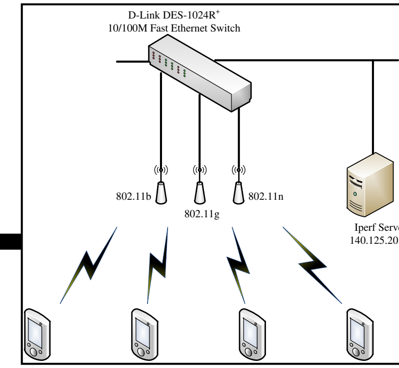
- **After 20s, WS 4 joins, disconnect WSs 1—3 and let WSs start connections**

WS 4	00:1F:3C:8B:14:F4	10000	802.11n
WS 2	00:1F:3C:8A:CD:91	9985	802.11n
WS 3	00:1F:3C:8B:13:10	9980	802.11g
WS 1	90:21:55:DD:9B:E3	9970	802.11b

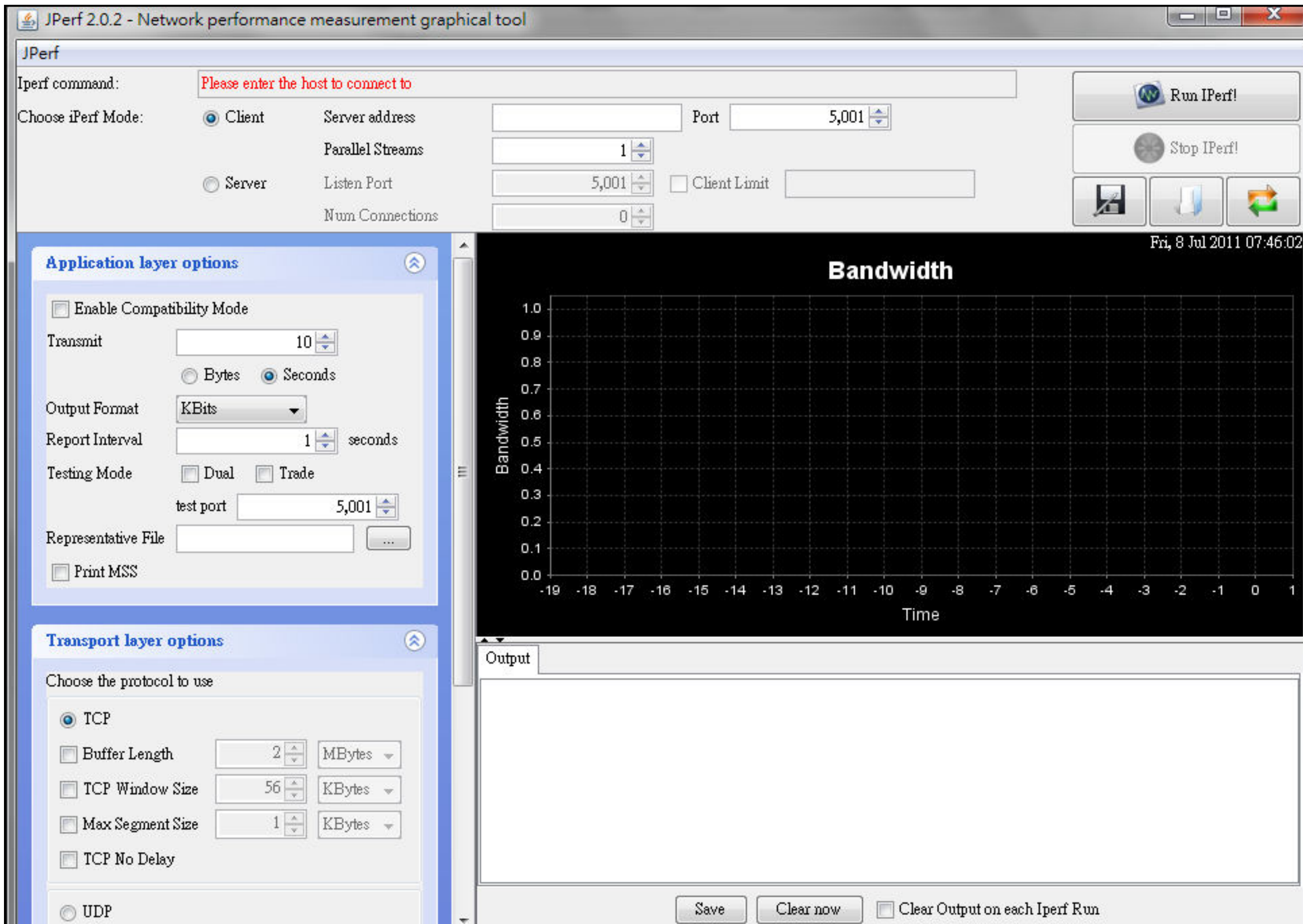
Field tests ensure our scheme operates as expected

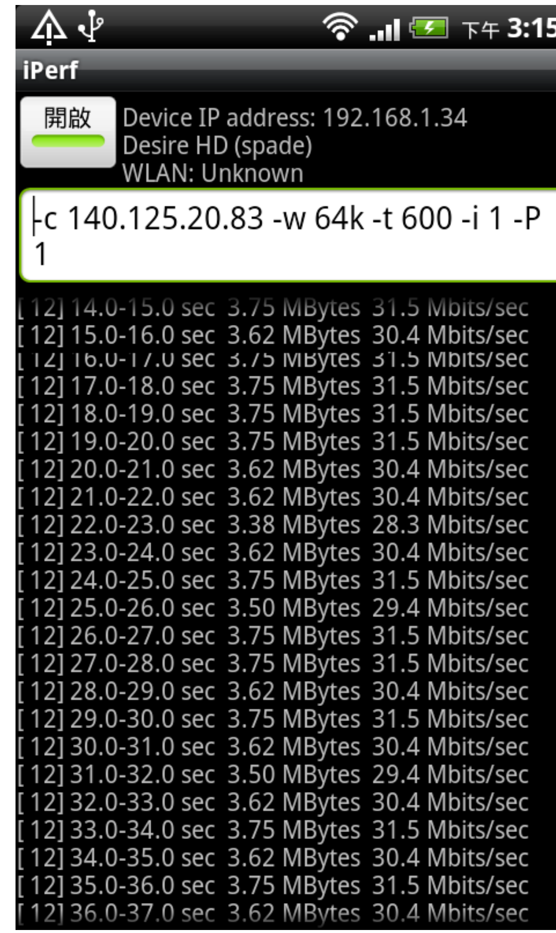
Performance

Evaluation

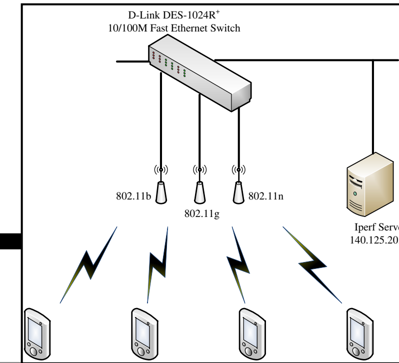


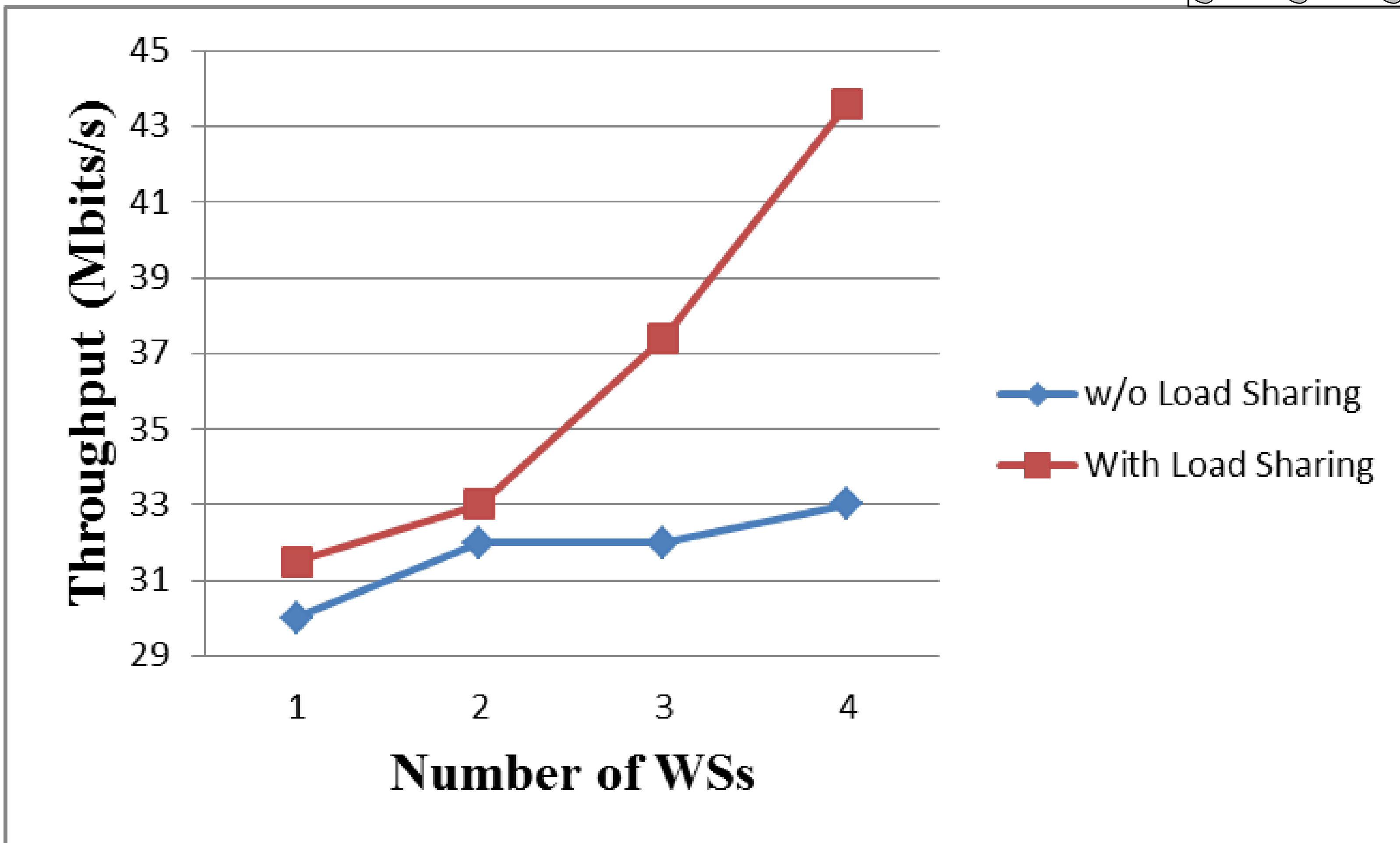
- **Use Iperf and Iperf for Android**
- **Measure throughput between the server and clients**



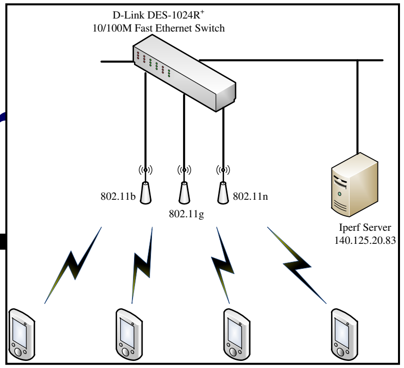


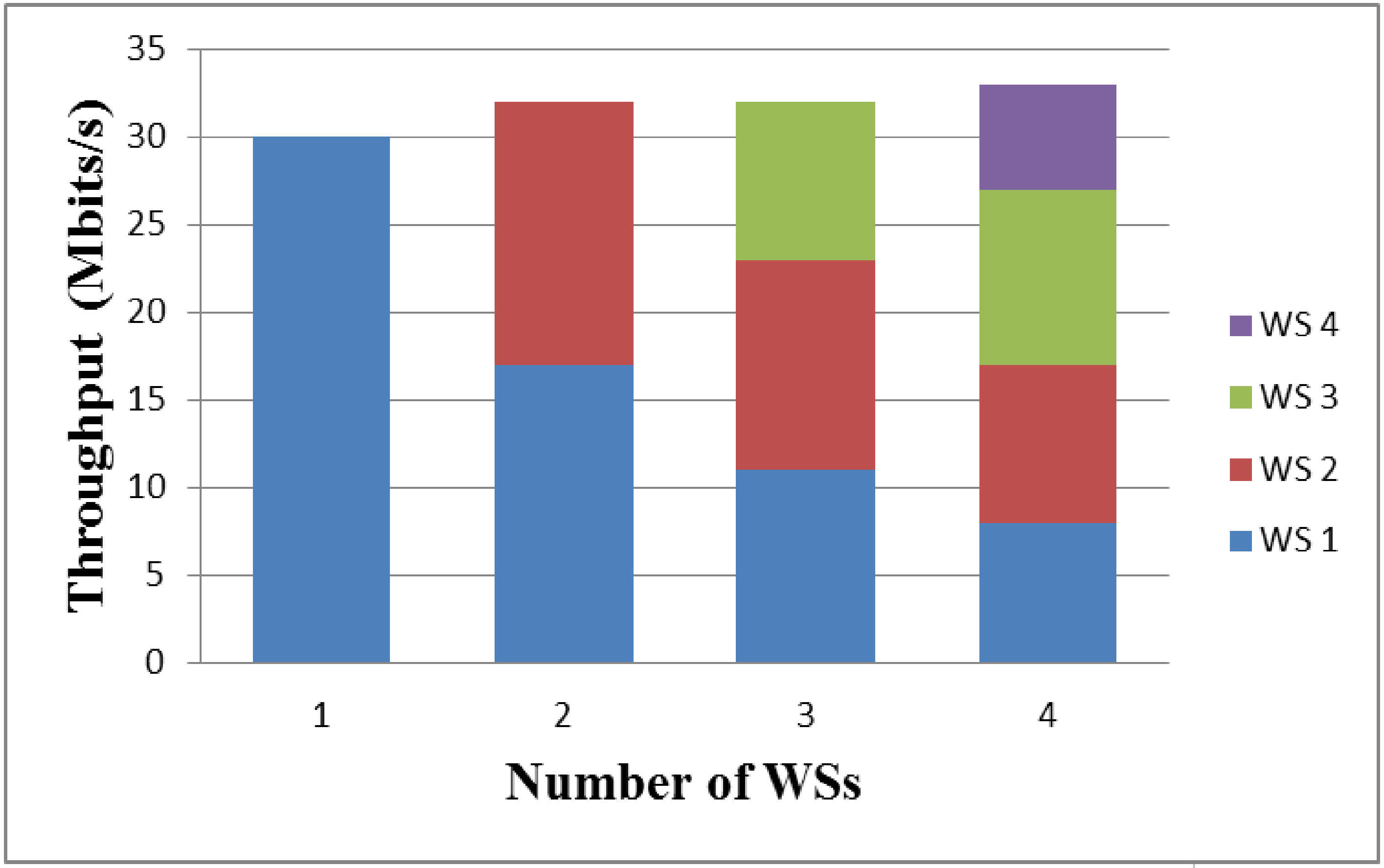
Aggregate Throughput



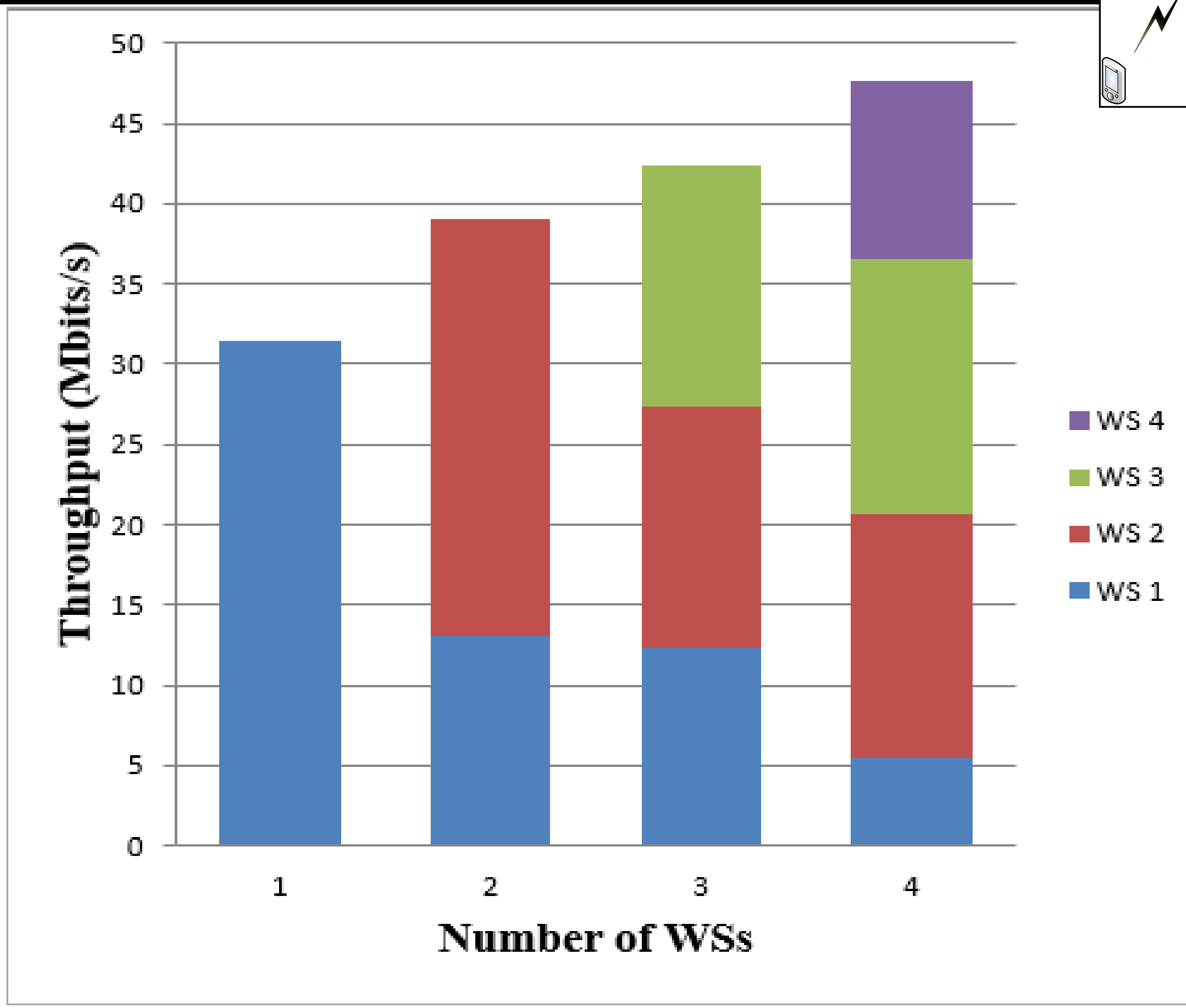


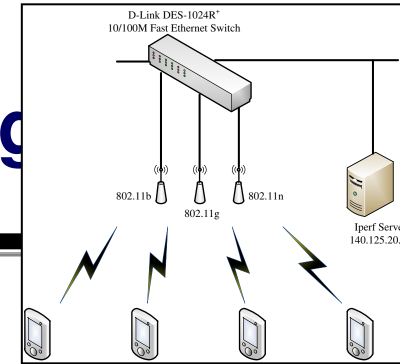
Respective Throughput (w/o Load Sharir



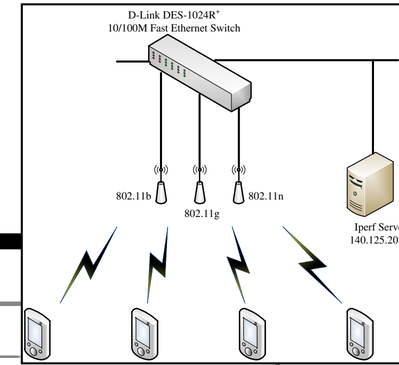


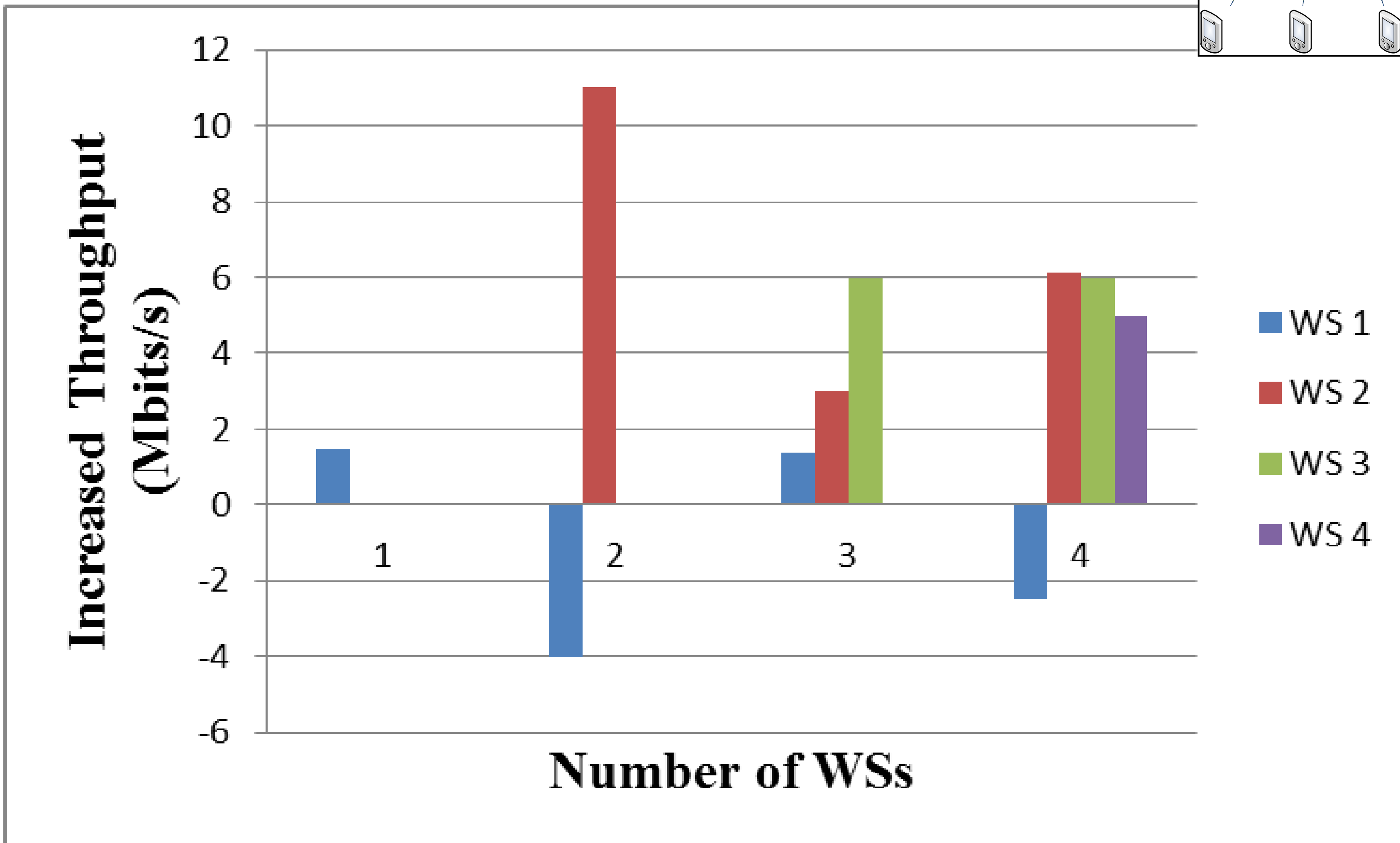
Respective Throughput (w/ Load Sharing





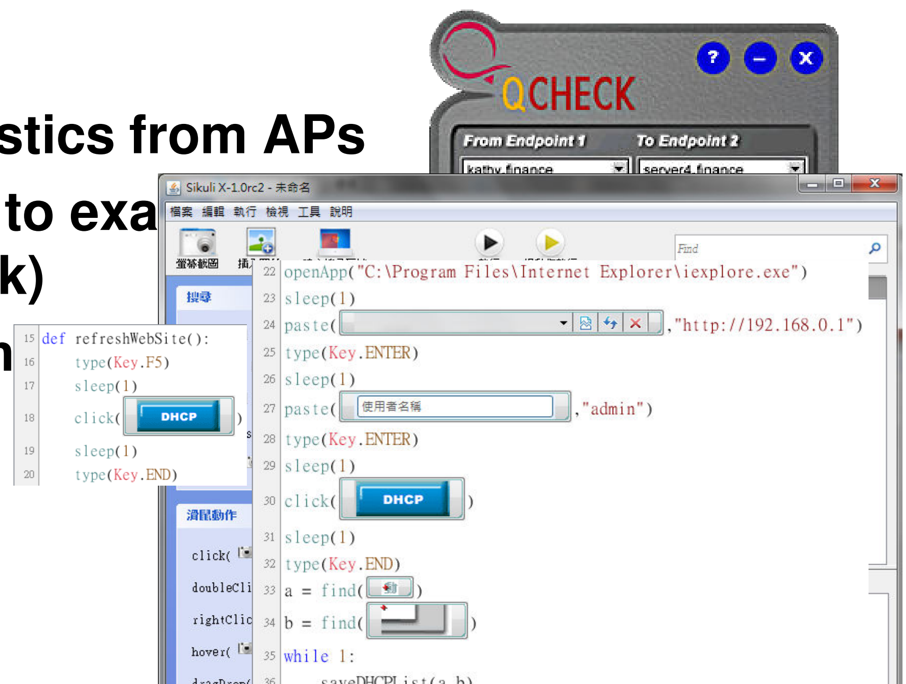
Increase of Throughputs





Summary

- **Load sharing among capability-varying APs has been shown effective**
  - **Overall throughputs ↑**
  - **Respective throughputs also increase significantly**
  - **Iperf server co-located at the IEEE 802.21 Information Server**
  - **Can be refined to operate in a distributed manner**
- **Future**
  - **May use SNMP to collect statistics from APs**
  - **May use other utility software to exa performance variation (Qcheck)**
  - **Use Sikuli to adjust AP's room according to load dynamics**



Q & A

Thank You

For any questions, please contact
chikh@yuntech.edu.tw