Inhomogeneous Wireless Network Load Distribution

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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.
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)
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
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?
(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 accumulate same entries.
(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.)
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
- $\mu()$: 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
  \[ \mu(r_{i,J}) \left( \sum_{j \in S} 1/ \mu(r_{j,j}) \right)^{-1} \]
- A best-fit AP is given by
  \[ \arg \max_X \mu(r_{i,X}) \left( \sum_{\forall j \in S_X} \frac{1}{\mu(r_{j,X})} \right)^{-1} \]

Our Approach
- centralized -
Our Approach (1/4)

Network settings

- Maintain a list of **points** (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

<table>
<thead>
<tr>
<th>MAC Address</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>90:21:55:DD:9B:E3</td>
<td>9980</td>
</tr>
<tr>
<td>...</td>
<td></td>
</tr>
<tr>
<td>00:1F:3C:8B:14:F4</td>
<td>9805</td>
</tr>
</tbody>
</table>

$t_1 = 2015.08.10 \ 10:20:50$

Server  | Handset
---------|---------
Select AP to connect [According to points list $L$] | Connect
Timestamp the connection $t_0$ | User decides to disconnect
Timestamp the disconnect $t_1$ | Modify points by connection time ($t_1 - t_0$)
Send Request($t_1 - t_0$) to server | Send Response $L$ to handset
Receive Request($t_1 - t_0$) | Disconnect completely
Update points list $L$ |
## Our Approach (3/4)

### Grading policy

<table>
<thead>
<tr>
<th>AP type</th>
<th>802.11b</th>
<th>802.11g</th>
<th>802.11n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Update principle</td>
<td>Points increase with connection duration</td>
<td>Neutral</td>
<td>Points decrease with connection duration</td>
</tr>
<tr>
<td>Points adjustment</td>
<td>1*(connection duration) (s)</td>
<td>Invariant</td>
<td>(-1)*(connection duration) (s)</td>
</tr>
</tbody>
</table>
Our Approach (4/4)

- 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 a new WS joins, disconnect previous WSs and re-start connections
  - 4 WSs first connected with 802.11n AP
  - Investigate how our scheme performs

[Diagram showing network setup with wireless stations, APs, and Iperf Server]
Experiments (2/3)

- WS 1 connected to IEEE 802.11n AP

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>WS 1</td>
<td>90:21:55:DD:9B:E3</td>
<td>10000</td>
<td>802.11n</td>
<td></td>
</tr>
</tbody>
</table>

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

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>WS 2</td>
<td>00:1F:3C:8A:CD:91</td>
<td>10000</td>
<td>802.11n</td>
<td></td>
</tr>
<tr>
<td>WS 1</td>
<td>90:21:55:DD:9B:E3</td>
<td>9990</td>
<td>802.11g</td>
<td></td>
</tr>
</tbody>
</table>

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

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>WS 3</td>
<td>00:1F:3C:8B:13:10</td>
<td>10000</td>
<td>802.11n</td>
<td></td>
</tr>
<tr>
<td>WS 1</td>
<td>90:21:55:DD:9B:E3</td>
<td>9990</td>
<td>802.11n</td>
<td></td>
</tr>
<tr>
<td>WS 2</td>
<td>00:1F:3C:8A:CD:91</td>
<td>9985</td>
<td>802.11g</td>
<td></td>
</tr>
</tbody>
</table>
Experiments (3/3)

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

<table>
<thead>
<tr>
<th>Device</th>
<th>MAC Address</th>
<th>Client ID</th>
<th>Band</th>
</tr>
</thead>
<tbody>
<tr>
<td>WS 4</td>
<td>00:1F:3C:8B:14:F4</td>
<td>10000</td>
<td>802.11n</td>
</tr>
<tr>
<td>WS 2</td>
<td>00:1F:3C:8A:CD:91</td>
<td>9985</td>
<td>802.11n</td>
</tr>
<tr>
<td>WS 3</td>
<td>00:1F:3C:8B:13:10</td>
<td>9980</td>
<td>802.11g</td>
</tr>
<tr>
<td>WS 1</td>
<td>90:21:55:DD:9B:E3</td>
<td>9970</td>
<td>802.11b</td>
</tr>
</tbody>
</table>

Field tests ensure our scheme operates as expected
Performance
Evaluation

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

802.11b
802.11g
802.11n
Iperf Server
140.125.20.83
D-Link DES-1024R+
10/100M Fast Ethernet Switch
Aggregate Throughput
Respective Throughput (w/o Load Sharing)

<table>
<thead>
<tr>
<th>Network</th>
<th>Throughput (Mbits/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>802.11b</td>
<td></td>
</tr>
<tr>
<td>802.11g</td>
<td></td>
</tr>
<tr>
<td>802.11n</td>
<td></td>
</tr>
</tbody>
</table>

Iperf Server: 140.125.20.83
D-Link DES-1024R + 10/100M Fast Ethernet Switch
Respective Throughput (w/ Load Sharing)

![Diagram showing throughput comparison with different numbers of WSs]

- **802.11b**
- **802.11g**
- **802.11n**

- **Iperf Server**: 140.125.20.83
- **D-Link DES-1024R +** 10/100M Fast Ethernet Switch
Increase of Throughputs

- 802.11b
- 802.11g
- 802.11n
- Iperf Server
- 140.125.20.83
- D-Link DES-1024R
- 10/100M Fast Ethernet Switch

![Graph showing increased throughput with number of WSs]
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 examine performance variation (Qcheck)
- Use Sikuli to adjust AP’s room online according to load dynamics
Thank You

Q & A

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