Backhaul Virtualization for Multiple Services in Public WLANs

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Outline

1. Background
   • Heavy use of public wireless LAN
   • Expectation for bandwidth guaranteed service

2. Proposed Method
   • Guaranteed bandwidth model in Public WLANs
   • Backhaul virtualization and bandwidth assignment

3. Performance Evaluation

4. Summary and Future Works
Background

• Higher performance terminal equipment and multiple services are widely spread.
  → The amount of data traffic is growing rapidly.

• Public WLANs are often used.
Target

• Effective throughput degrades significantly when many users connect to single access point (AP).

Bandwidth guaranteed services are expected.

Propose guaranteed bandwidth model in Public WLANs

• GBR (Guaranteed Bit Rate) user
  • Require constant bandwidth
    → If bandwidth cannot be guaranteed, user’s requirement is rejected.

• BE (Best Effort) user
  • Share bandwidth with other BE users
Propose Guaranteed Bandwidth Model

• GBR users install dedicated application in their user equipment (UE).
  • Authentication of UE

• Traffic shaping
  • Role of GateWay (GW) and UE’s application
  • Transmit packets to backhaul without exceeding guaranteed bandwidth

• Set flow per UE in backhaul
  → Maintain shaped bandwidth per flow

![Diagram showing the process of traffic shaping and setting flows per UE.]

- Install dedicated application
- Setting a flow per UE
- Traffic shaping
- Backhaul
- Server
- AP
- UE
Network Model

• Virtual AP area
  • BE and GBR virtual APs are configured with multiple APs [1].
  • # of assigned physical APs are changed according to arrival ratio.

• A-GW (Access Point GateWay)
• AP NW (Access Point NetWork)
• B-GW (Backbone GateWay)
• SDN Controller
• AP Controller

AP Virtualization

- Configure BE and GBR virtual APs[1]
  - Each virtual AP is configured with multiple physical APs.
  - Each physical AP has ESSID of GBR or BE.
    - AP Controller selects a physical AP a user should be connected to.
  - A physical AP cannot be assigned to both virtual APs simultaneously.
    - It enables an AP to provide constant bandwidth to GBR users.

Red: Physical APs assigned to GBR virtual AP  Black: Physical APs assigned to BE virtual AP

Users can see only virtual APs.
Backhaul Virtualization

• Mixed traffic of GBR and BE in backhaul
  \[\rightarrow\text{GBR} \, \& \, \text{BE}\] traffic should be isolated to achieve guaranteed bandwidth for GBR users.

• Network virtualization
  • BE \, \& \, GBR virtual networks (slices) are configured in the physical network
Bandwidth Assignment to Each Service

• Wireless
  • Assign physical AP for each service [1]

• Backhaul
  • Between A-GW and UEs:
    • GBR: assign bandwidth per UE
    • BE: assign bandwidth per physical AP
  • Between B-GW and A-GWs:
    • Hard to set flow per UE
    • Set aggregated flow per A-GW
      → Assign rich bandwidth
Issue of Backhaul Bandwidth Assignment

• BE bandwidth **diminishes remarkably** when excess bandwidth is assigned to GBR.

• Assignment should be changed **dynamically**.

Achieve target call-blocking probability of GBR users and improve satisfaction degree of BE users

• Bandwidth assignment in wireless links
• Bandwidth assignment between B-GW and A-GW
Bandwidth Assignment in Wireless Links

- Change physical APs assigned to each virtual AP at a constant time interval[1]
  - First, assign physical APs to GBR virtual AP
  - Set bandwidth for arriving GBR users per physical AP (ensured bandwidth)

Red: Physical APs assigned to GBR virtual AP  Black: Physical APs assigned to BE virtual AP

After a certain period of time

increase # of GBR users
Bandwidth Assignment between B-GW and A-GW

• Change assignment between B-GW and A-GWs at a constant time interval $T$
  • GBR bandwidth = ongoing GBR users’ bandwidth
    + $Increased$-$predicted$ $bandwidth$

• Predict $Increased$-$predicted$ $bandwidth$ based on past GBR bandwidth variation

![Diagram of bandwidth assignment between B-GW and A-GW]
Increased-predicted Bandwidth prediction

• Predict based on average of the largest past bandwidth increase
  • Average increase variation of each time interval
  • Weight averaging intervals according to # of GBR users

Increased predicted bandwidth:

\[ B_{\text{pre}} = \frac{\sum_{i=k-1}^{k-n-1} \alpha_i (B_{\text{max}_i} - B_i)}{\sum_{i=k-1}^{k-n-1} \alpha_i} \]

Weight parameter:

\[ \alpha_i = \frac{u_k}{u_k + |u_k - u_i|} = \begin{cases} 
\frac{u_k}{2u_k-u_i} (u_i \leq u_k) \\
\frac{u_k}{u_i} (u_i > u_k)
\end{cases} \]

\( t_k \): current assignment time
\( u_i \): # of GBR users at \( t_i \)
\( T \): Bandwidth assignment interval
\( B_{\text{max}_i} \): maximum GBR bandwidth at \( [t_{i-1}, t_i] \)
\( B_i \): GBR bandwidth at \( t_i \)
Evaluation Model

• Users
  • Whole arrival rate : 0.04 (Poisson arrival process)
    • GBR users required 2.0 [Mbps] with mean 3.5 [min].
    • BE users require 52.5 [MB] file download.
  • Arrival ratio of BE and GBR users : \( r : (1 - r) \)

• Compared methods
  • F-BH: divides bandwidth of B-GW equally to each service
  • RF-BH: assigns bandwidth of B-GW to GBR and BE services according to arrival ratio
    (arrival ratio is assumed to be given)

※ Physical AP assignment is same as the proposed method.
• The proposed method *always* achieved target call-blocking probability and obtained higher satisfaction degree.

→ The proposed method achieved **flexible** assignment according to arrival ratio.

\[ T: \text{Bandwidth assignment interval between B-GW and A-GW} \quad r: \text{Arrival ratio of BE user} \]
Evaluation with Varying $T$

- Call-blocking probability of GBR users

- Average satisfaction degree of BE users

- The proposed method outperforms F-BH and RF-BH when $T \leq 100$.

- # of A-GWs that can be supported
  \[ T \geq \frac{10}{1000} \times m \quad (m:\# \text{ of A-GW})\]
  Setting a flow takes 10[ms]

  10000 A-GWs can be connected to the proposed model.

$T$: Bandwidth assignment interval between B-GW and A-GW  
$r$: Arrival ratio of BE user
Summary and Future Works

• Summary
  • Propose network model for bandwidth guarantee in Public WLANs
  • Backhaul Virtualization in proposed model
    • Bandwidth assignment for GBR and BE
  • Performance evaluation by simulation
    • Call blocking probability for GBR users
    • Average satisfaction degree of BE users

• Future works
  • Enhance method to consider mobility of users and ARF (Auto Rate Fallback)