Backhaul Virtualization for Multiple Services in Public WLANs

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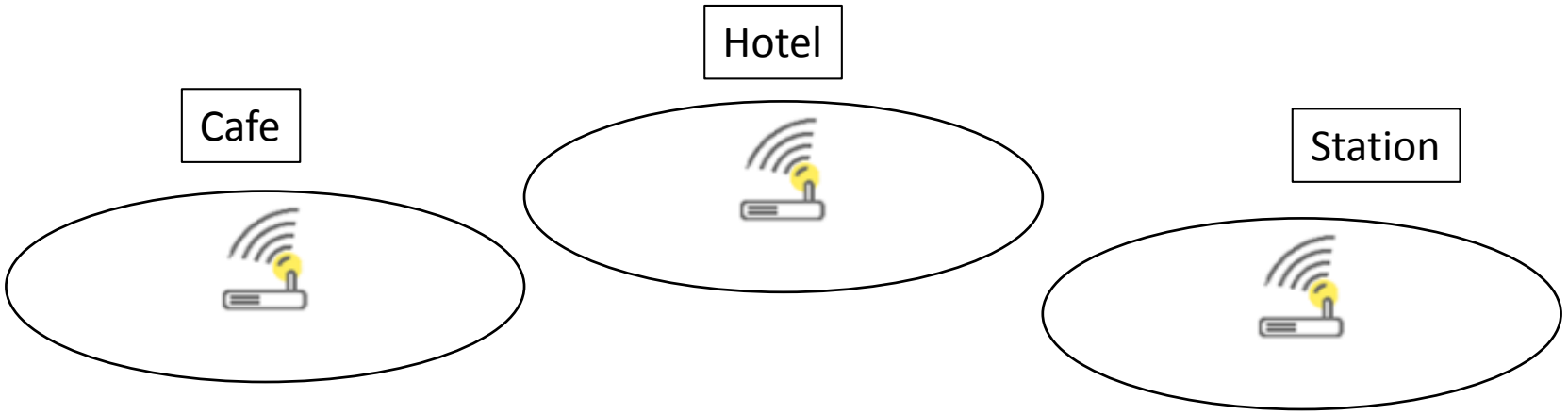
Outline

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.

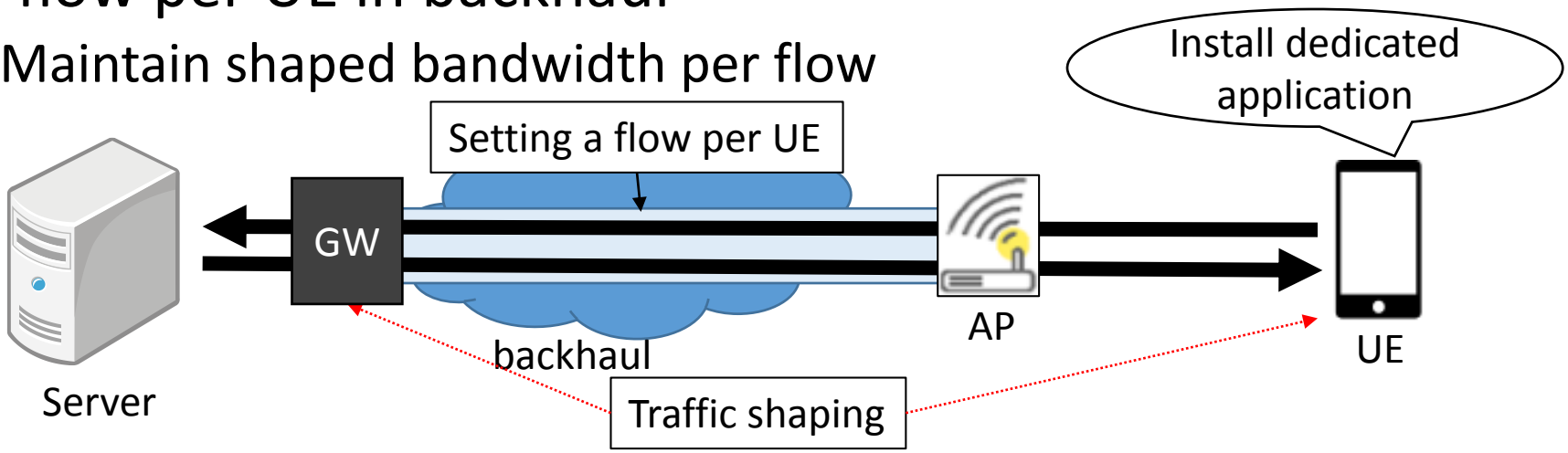
Propose guaranteed bandwidth model in Public WLANs

- 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

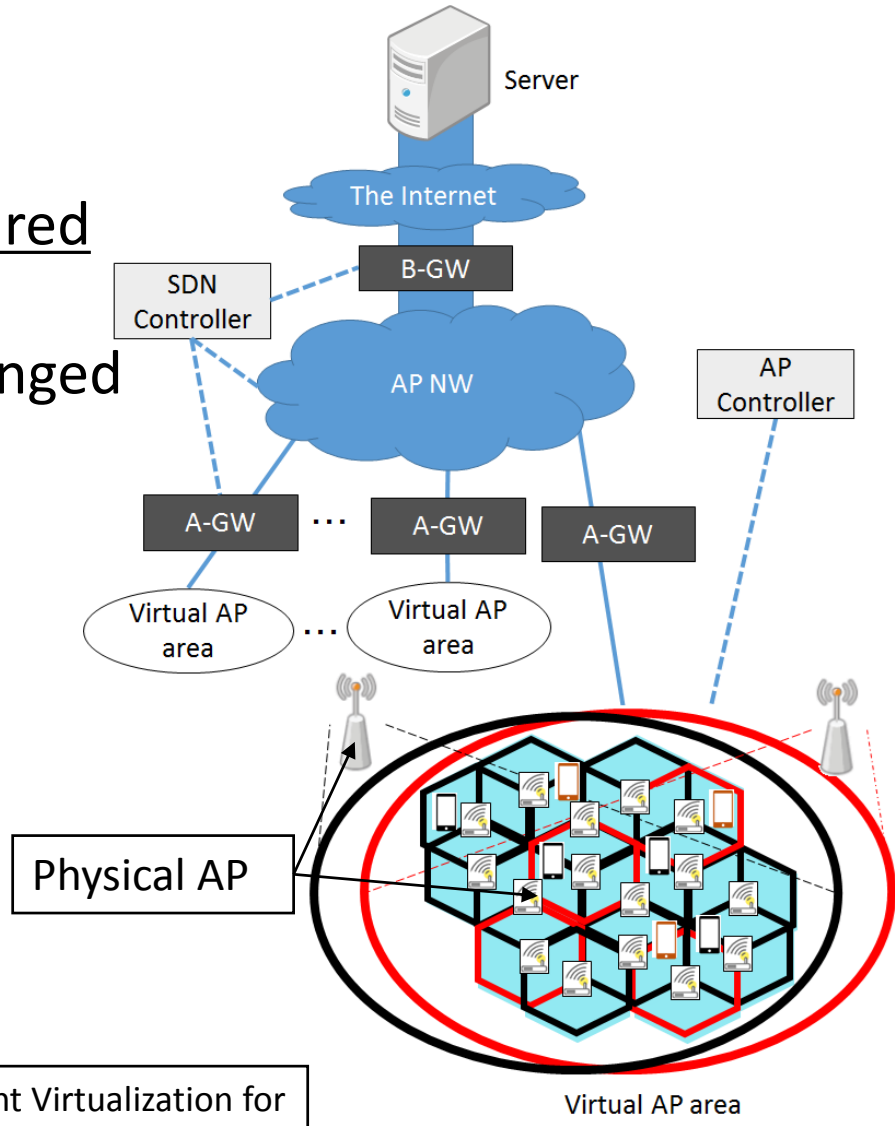
- GBR users install dedicated application in their user equipment (UE).
  - Authentication of UE
- Traffic shaping
  - Role of GateWay (GW) and UE's application
  - Transmit packets to backhaul without exceeding guaranteed bandwidth
- Set flow per UE in backhaul

  →Maintain shaped bandwidth per flow



Network Model

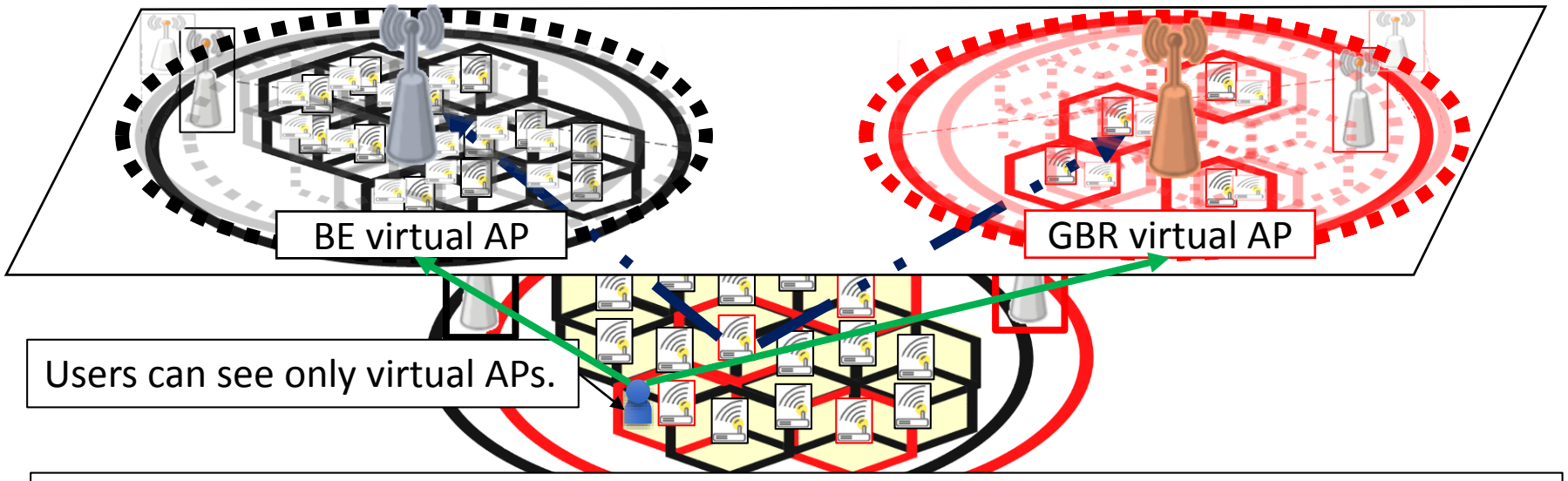
- Virtual AP area
  - BE and GBR virtual APs are configured with multiple APs [1].
  - # of assigned physical APs are changed according to arrival ratio.
- A-GW(Access Point GateWay)
- AP NW (Access Point NetWork)
- B-GW(Backbone GateWay)
- SDN Controller
- AP Controller



[1] K. Ginnan, K. Kawano, K. Kinoshita, T. Watanabe, ``Access Point Virtualization for Multiple Services in Heterogeneous WLANs,'' 14th Annual IEEE Consumer Communications & Networking Conference (CCNC2017), Jan. 2017.

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 enable an AP to provide constant bandwidth to GBR users.

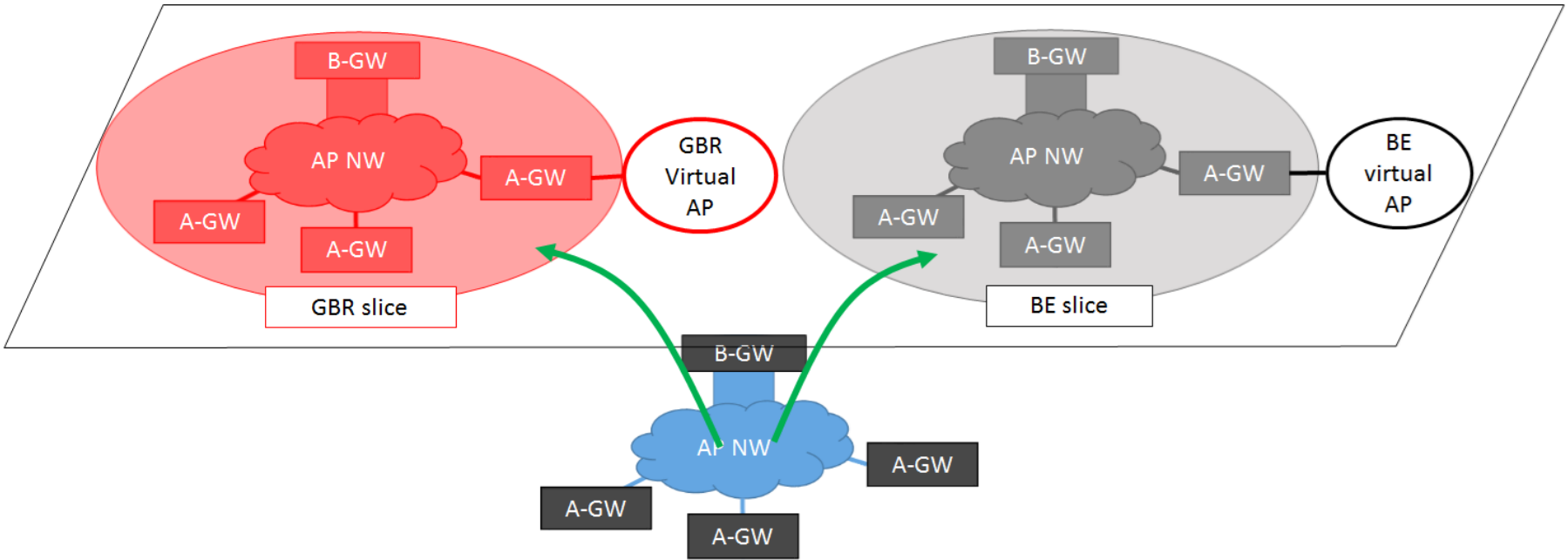


Backhaul Virtualization

- Mixed traffic of GBR and BE in backhaul

  →GBR・BE traffic should be isolated to achieve guaranteed bandwidth for GBR users.

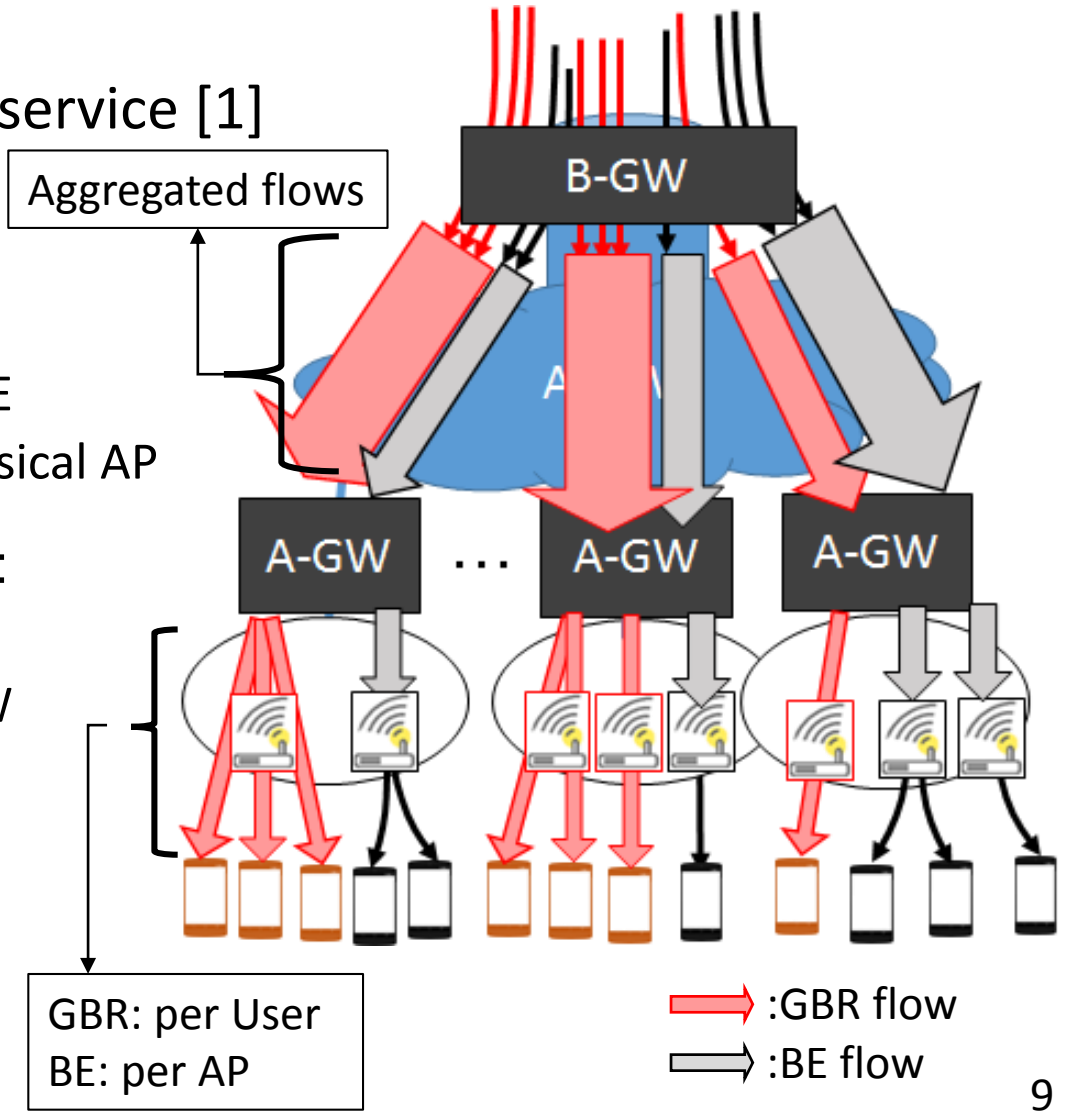
- Network virtualization
  - BE・GBR virtual networks (slices) are configured in the physical network



Bandwidth Assignment to Each Service

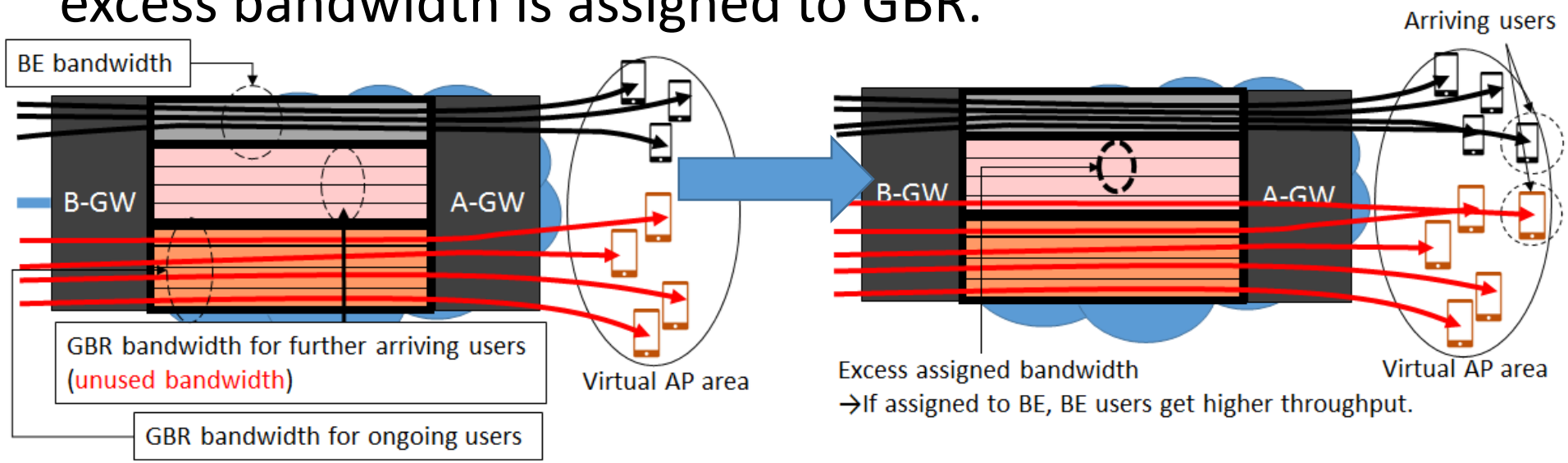
- Wireless
  - Assign physical AP for each service [1]
- Backhaul
  - Between A-GW and UEs :
    - GBR : assign bandwidth per UE
    - BE : assign bandwidth per physical AP
  - Between B-GW and A-GWs :
    - Hard to set flow per UE
    - Set aggregated flow per A-GW

    →Assign rich bandwidth



Issue of Backhaul Bandwidth Assignment

- BE bandwidth diminishes remarkably when excess bandwidth is assigned to GBR.



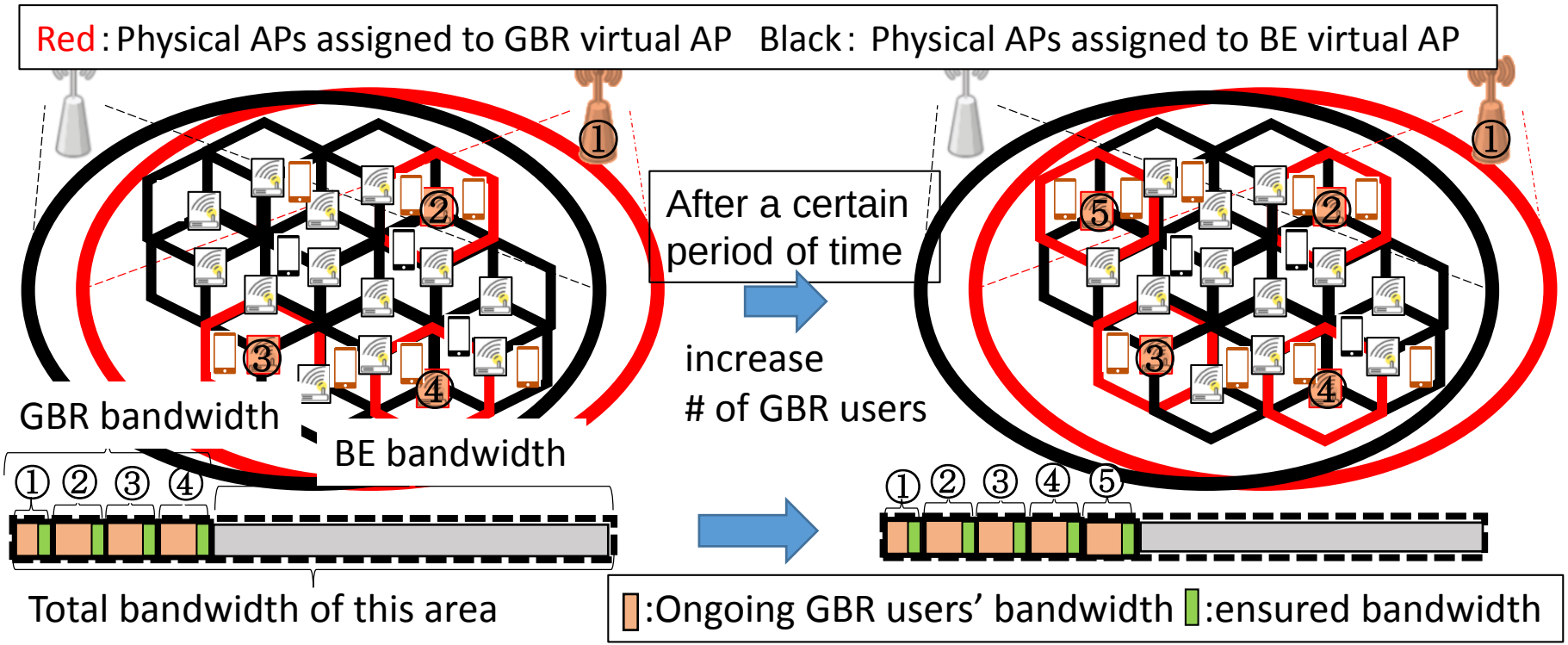
- Assignment should be changed dynamically.

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

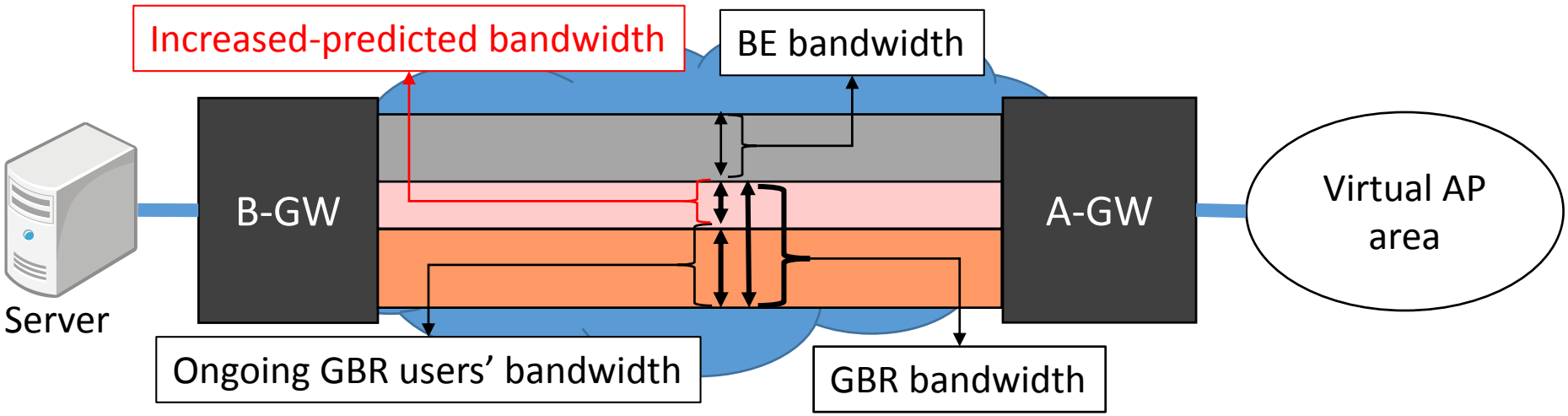
Bandwidth Assignment in Wireless Links

- 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)



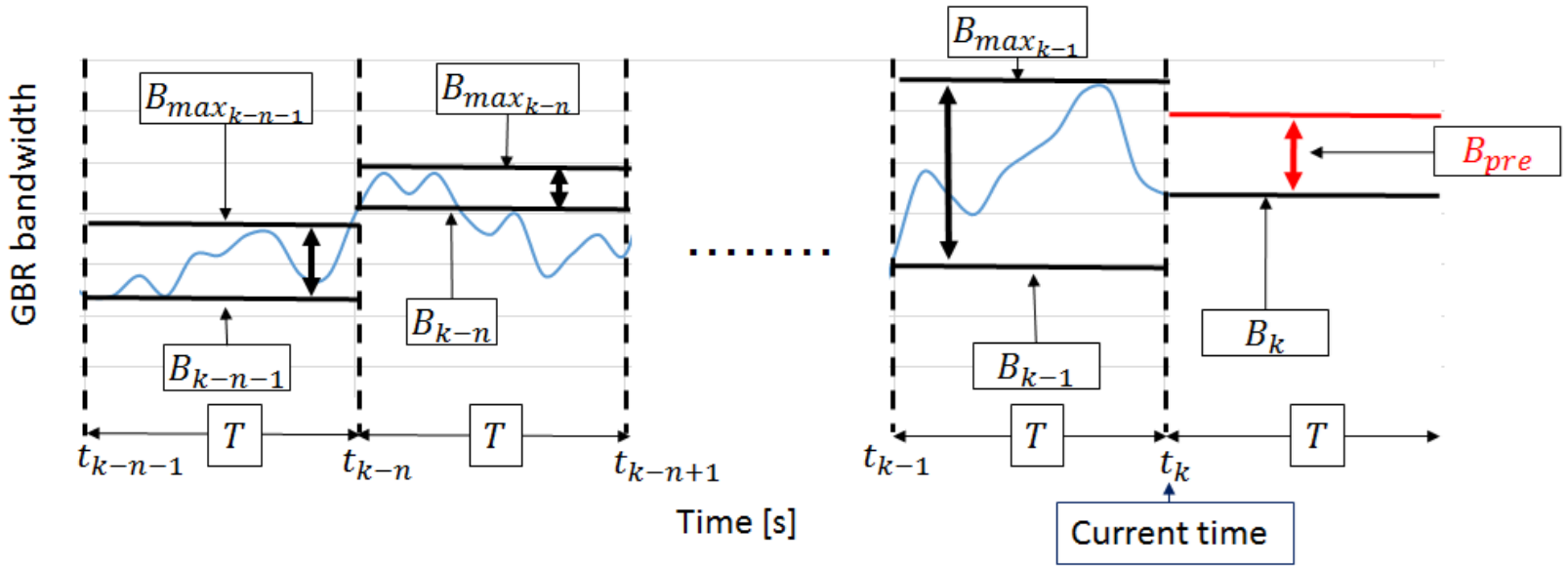
Bandwidth Assignment between B-GW and A-GW

- 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



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: $$B_{pre} = \frac{\sum_{i=k-1}^{k-n-1} \alpha_i (B_{max_i} - B_i)}{\sum_{i=k-1}^{k-n-1} \alpha_i}$$

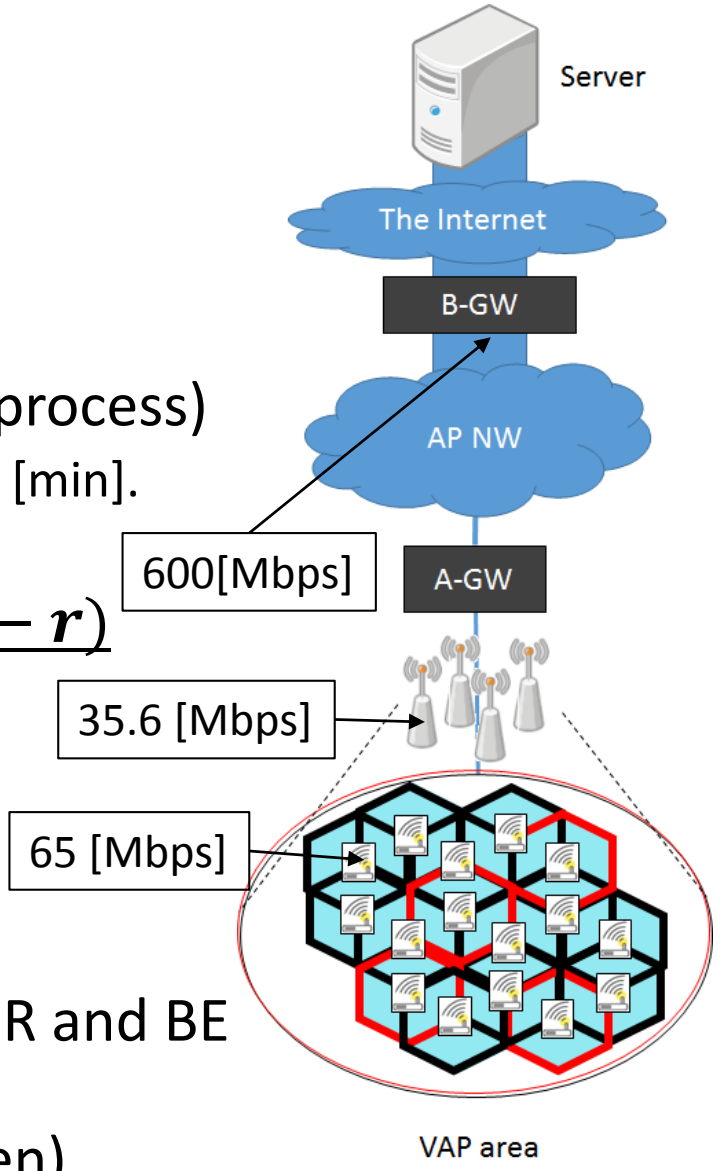
Weight parameter: $$\alpha_i = \frac{u_k}{u_k + |u_k - u_i|} = \begin{cases} \frac{u_k}{2u_k - u_i} (u_i \le u_k) \\ \frac{u_k}{u_i} (u_i > u_k) \end{cases}$$

t_k:current assignment time
u_i: # of GBR users at t_i
T:Bandwidth assignment interval
B_{max_i} : maximum GBR bandwidth at $[t_{i-1}, t_i]$
B_i:GBR bandwidth at t_i

Evaluation Model

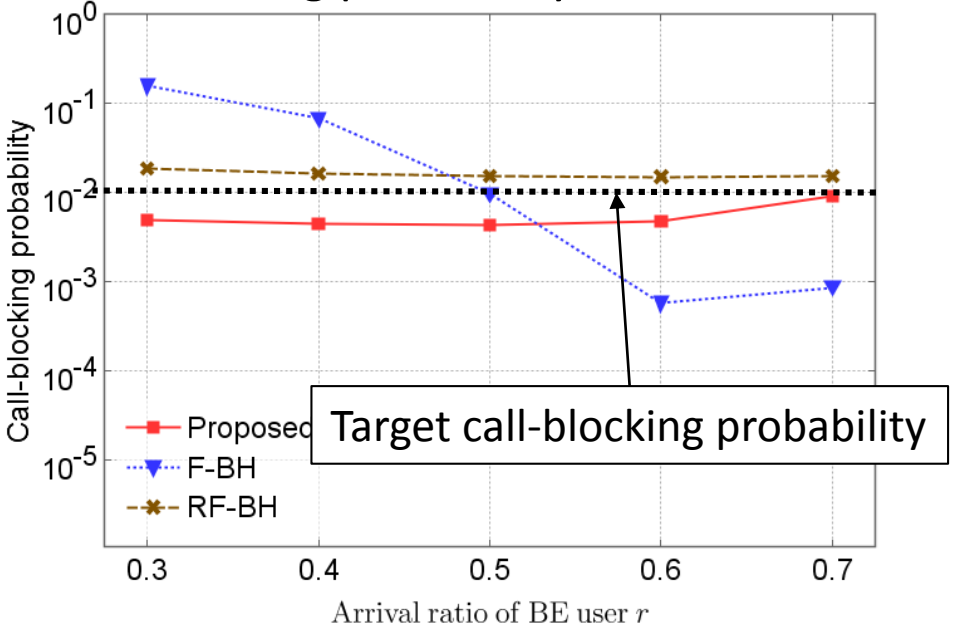
- Users
  - Whole arrival rate : 0.04 (Poisson arrival process)
    - GBR users required 2.0 [Mbps] with mean 3.5 [min].
    - BE users require 52.5 [MB] file download.
  - Arrival ratio of BE and GBR users : $\boldsymbol{r : (1 - r)}$
- Compared methods
  - F-BH: divides bandwidth of B-GW equally to 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.

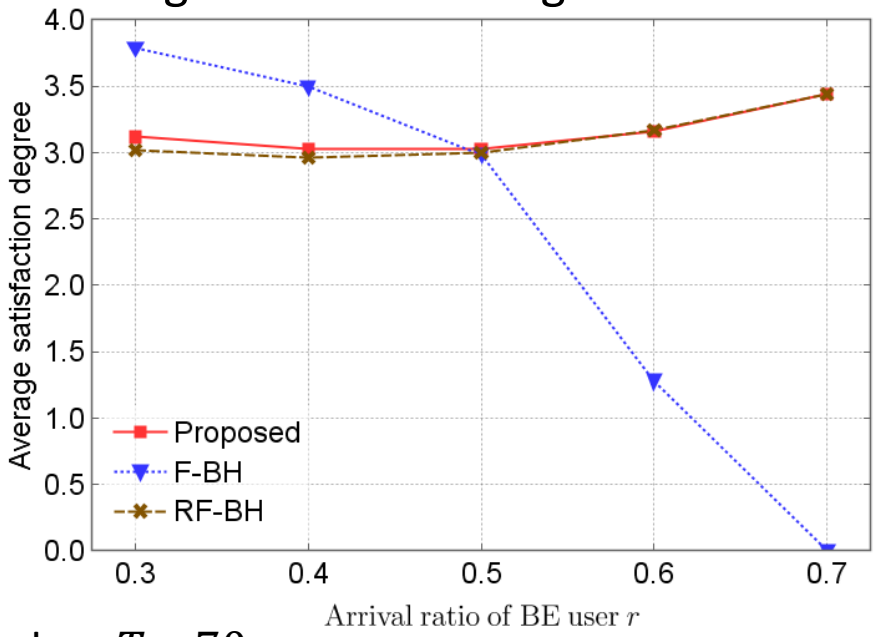


Evaluation with Varying r

- Call-blocking probability of GBR users



- Average satisfaction degree of BE users



The evaluation when $T = 70$

※Satisfaction degree of BE users : $\log R$ R:BE user's throughput

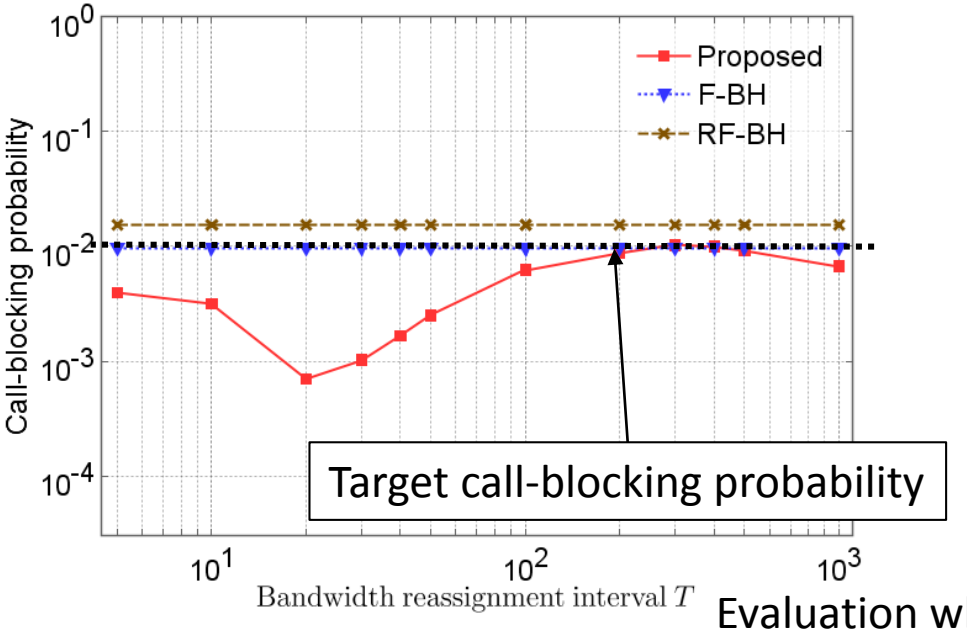
- The proposed method always achieved target call-blocking probability and obtained higher satisfaction degree.

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

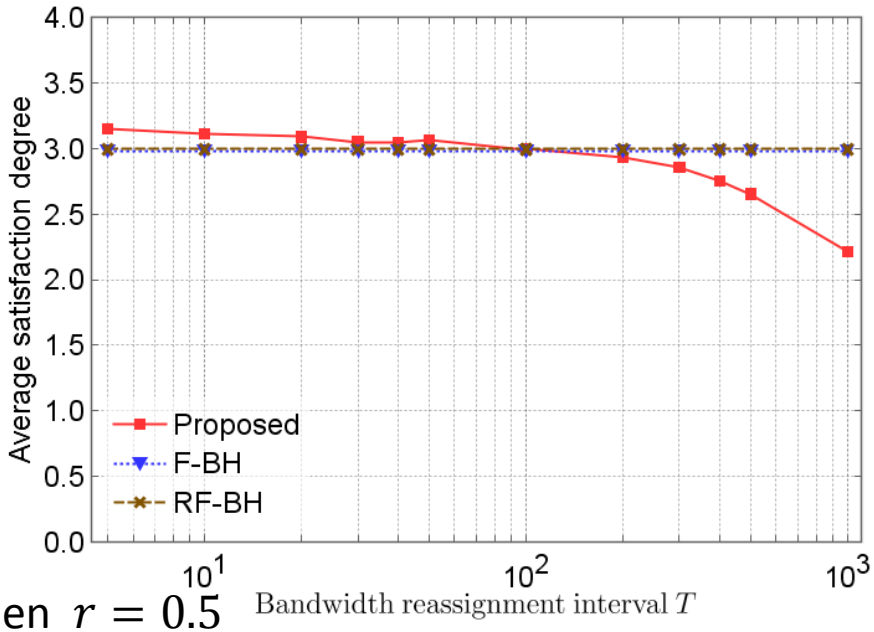
T:Bandwidth assignment interval between B-GW and A-GW r: Arrival ratio of BE user

Evaluation with Varying T

- Call-blocking probability of GBR users



- Average satisfaction degree of BE users



Evaluation when $r = 0.5$

- The proposed method outperforms F-BH and RF-BH when $T \leq 100$.
- # of A-GWs that can be supported

$\rightarrow T \geq \frac{10}{1000} \times m$ (m:# 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)