A Proposal of Gateway Decentralization Method in Wireless Mesh Networks and Its Evaluation

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1 Introduction

Wireless ad-hoc networks have been studied as one of the utilization methods of wireless LANs. In wireless ad-hoc networks, end terminals can communicate with each other with the support of intermediate terminals relaying packets even if the end terminals are mutually located out of their wireless ranges. However, its utilization has been limited due to the problem that resources of intermediate terminals are used regardless of user's will and also, communication routes are not stable when the end terminals move. Recently, wireless mesh networks applying the wireless ad-hoc network are drawing much attention. In the wireless mesh networks, an AP (Access Point), which is connected by wire in conventional systems, is connected by a wireless ad-hoc network. The wireless range can easily be extended and as a result, it is expected that the wireless mesh network is used as the method of building communication infrastructure and also as emergency networks at the time of disaster, etc.

In the wireless mesh networks, it is well recognized that the communication throughput improves when the number of hops from a terminal to the GW (Gateway) is smaller. Thus, in order to attain the high communication throughput, various ways of selecting the most suitable GW among several GWs (installed between the wireless mesh network and the external network) have been studied. In concrete, there is, for instance, a way of relaying the packet received from the AP to the GW with the least number of hops among multiple GWs. However, when the same GW is used by many terminals at the same time, the GW consumes its bandwidth to the maximum limit while the bandwidths of other GWs are left open. Thus, various methods of utilizing all GWs in the most efficient way have been studied. Reference [1] demonstrates the way of relaying packets received from AP to different GWs according to the transmission ratio among plural GWs, determined based on a number of parameters. However, this method has a problem that the throughput tends to decrease due to the generation of packet jitter in the case of TCP communication.

In this paper, we propose a method of reducing the decrease in the TCP throughput and at the same time improving the utilization efficiency of the GWs, by way of transmitting to GWs "in sessions", instead of in packets.

2. Existing Technologies

In this paper, we introduce existing methods, by dividing the GW selection methods of the wireless mesh networks into two types; namely, one is the single GW selection method and the other the multi GW selection method.

2.1 Single GW Selection Method

The concept of the single GW selection method is quite simple. An AP selects a GW having the least number of hops. Reference [2] shows a method, which attempts to increase the efficiency of TCP by determining the location of GWs in an efficient manner. However, in the actual environment, there are often cases where the location of GWs is limited. Also, in the case of the single GW selection method, traffic tends to be directed to one GW when many terminals exist around this GW, while other GWs are left unused.

2.2 Multi GW Selection Method

Reference [1] proposes a method whereby an AP distributes packets to several GWs in order to solve the problem occurring in the case of the single GW selection method. The AP calculates the packet transmission ratio among multiple GWs based on a number of parameters such as the number of hops and the traffic spare values of transmission routes. When the AP receives packets from terminals, the packets are forwarded to GWs according to the determined transmission ratio. Then, GWs forward packets to an MGW (Master GW), which in turn transmits them to external terminals altogether. At this stage, an AP adds some delay to the transmission time for each packet based on the transmission time to each GW calculated beforehand, in order to avoid packet jitter. In this method, however, because routes of packets in the same session are different, order reversals of the packets often take place, causing delay in the rising of TCP windows. As a result, the window size tends to remain small and the throughput goes down.

3. Proposed Method

In this paper, we propose a method of distributing packets in sessions instead in packets. Hereafter, we call them "packet distribution method" and "session distribution method" (our proposed method).

3.3 WAPL

In order to compare and evaluate these two methods, we use "WAPL" (Wireless Access Point Link) that we are proposing as the basic Wireless Mesh Network. Figure1 shows the entire schematic picture of WAPL. In WAPL, the wireless AP is called "WAP" (Wireless Access Point), the WAP which is connected with the wire is called "GWAP" (Gateway WAP), and the GWAP which gathers packets and is connected with an external network is called "MGWAP" (Master GWAP). Communication with external networks is always relayed by the MGWAP. There should be no bottleneck for the communication between GWAP and an MGWAP as the connection is by wire. An MGWAP include the function of a GWAP.

GWAPs and an MGWAP periodically advertise the message with the number of hops and the traffic information around themselves by way of flooding. The number of hops is increased each time when a WAP is relayed. With this message, each WAP grasps the traffic value around each GWAP and the number of hops between itself and the GWAP.

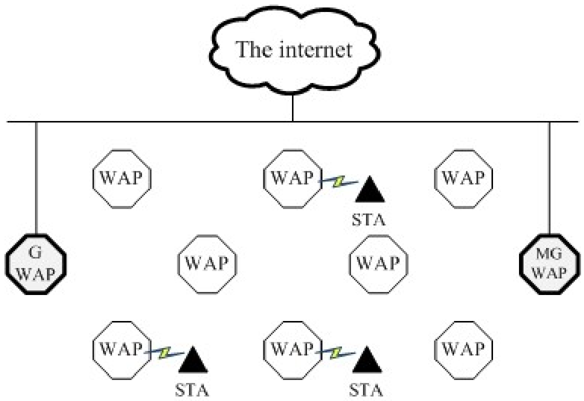

figure1. Entire Schematic Picture of WAPL

3.1 Session Distribution Method

Each time when the WAP receives a packet from a terminal, it determines the most suitable GWAP based on the traffic and hop number of the GWAP of that time. The packet in the same session thereafter is forwarded to the first selected GWAP. The session is identified by the session ID (IP address, port number, protocol number). The GWAP gathers received packets to the MGWAP, which relays packets to external terminals and memorizes the relations between the session and the GWAP which transmitted the packet. The packet in the same session from the external terminal is forwarded to the GWAP based on the information memorized by the MGWAP. In this way, the round trip of the same session passes the same route. When another session is initiated, the most suitable GWAP of that time is selected anew. In the case communication is initiated by an external terminal, the MGWAP, upon receipt of the packet, advertises a message inquiring the most suitable GWAP by way of flooding. The route is determined when the WAP to which the target terminal belongs replies the IP address of the most suitable GWAP.

3.3 Improved Packet Distribution Method

In order to make clear the effect of the session distribution method, we apply the packet distribution method to WAPL for the comparison. WAP determines the transmission ratio, by calculating the transmission efficiency based on the traffic and the number of hops of each GWAP. When a WAP receives packets from terminals, it distributes them to different GWAPs based on the transmission ratio. Then, GWAPs gather packets to the MGWAP. When the communication is initiated from an external terminal, it advertises a message inquiring the transmission ratio to GWAPs by way of flooding, upon receipt of the package. The WAP to which the target terminal belongs replies the transmission ratio to GWAPs. The MGWAP distributes packets to GWAPs based on the ratio. Here, it is possible to make the adjustment of time delay for each route, but this method tends to cause the problem of order reversal of packets. Accordingly, we present in this paper a method of controlling the order of packets by way of "queue" in WAP as well as in the MGWAP. The MGWAP forwards packets to external terminals after performing an order control. We call this method "improved packet distribution method" to distinguish it from the packet distribution method, described in Reference [1].

4. Evaluation by Simulation

We compared the influence to the TCP communication by the session distribution method and that by the improvement packet distribution method, by conducting a simulation. As the simulator, we used ns-2.

As shown in Figure 2, we set up a GWAP, a MGWAP and 5 WAPs in a row. We put the GWAP and the MGWAP on both ends. In this configuration, we connected 2 terminals to each WAP and prepared 2 TCP sessions. In order to make the evaluation for each number of hops of the GWAP and the MGWAP, we conducted the simulation by changing the terminal locations from A to B, to C.

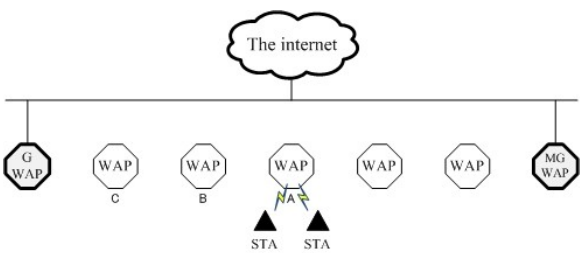

figure2 Simulation field

The results of this simulation are shown in Table 1. In the session distribution method, the closer the terminals come to C, the more the throughput of session 1 improves while the throughput of session 2 decreases. The reason is that session 2 avoids the traffic of session 1 and makes a connection with the MGWAP. In the improved packet distribution method, the closer the terminals come to C, the more the throughput decreases. The reason is that the delay in the packet transmitted from the WAP to the GWAP (MGWAP) having a larger number of hops increases, and this delay increases the delay in the whole session because of the order control by the MGWAP. That is to say, when a distance between the terminal and one of GWAP or MGWAP becomes far, the throughput decreases in the packet distribution method. On the other hand, in the session distribution method the throughputs remain the same as those corresponding to the number of hops in each session. Accordingly, when we compare the total throughputs, the session distribution method shows higher figures, and it is clear that the utilization efficiency improves by the proposal method.

Table.1 Comparison of throughputs

location		A	B	C
packet distribution method	Session 1	2.6	2.1	1.5
	Session 2	1.8	1.6	1.2
	Total	4.4	3.7	2.7
session distribution method	Session 1	3.4	5.9	10.6
	Session 2	2.7	1.6	1.7
	Total	6.1	7.5	12.3

[unit:Mbps]

5. Conclusion

We proposed the session distribution method as one of the multi GW selection methods. Based on the results of the simulation, we came to the conclusion that the TCP throughput becomes larger in the session distribution method compares with the session distribution method. As the next step, we are going to make the implementation of the session distribution method.

Reference

[1] Lakshmanan, S., Sundarean, K and Sivakumar, R, “On Multi-Gateway Association in Wireless Mesh Networks”, WiMesh 2006; Second IEEE Workshop on Wireless Mesh Networks, pp.64-73, Sep.2006.

[2] Yoshida, S., Funabiki, N and Nakanisi, T., “A Development of Wireless Infrastructure Mesh Network Simulator”, Technical report of IEICE.

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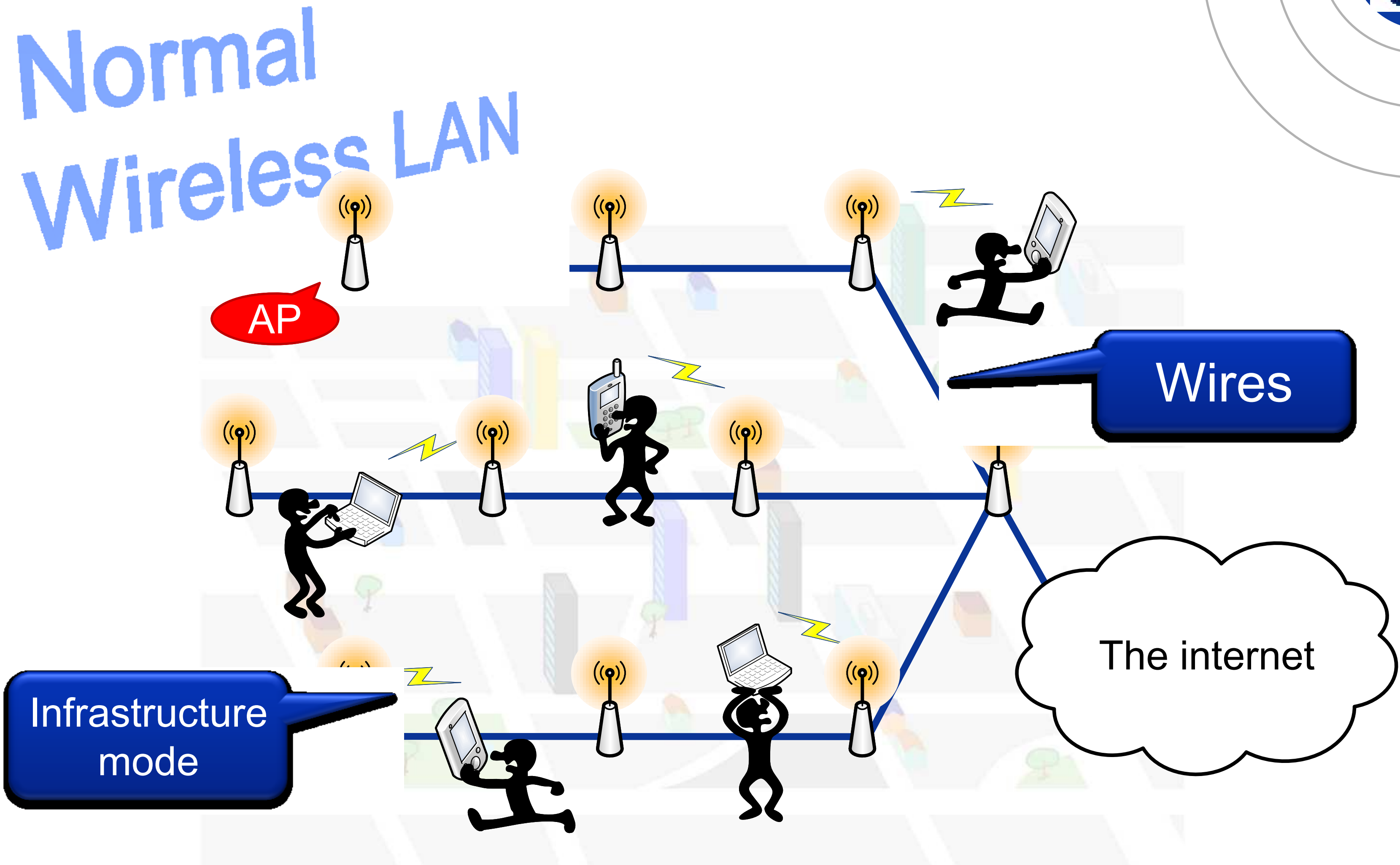
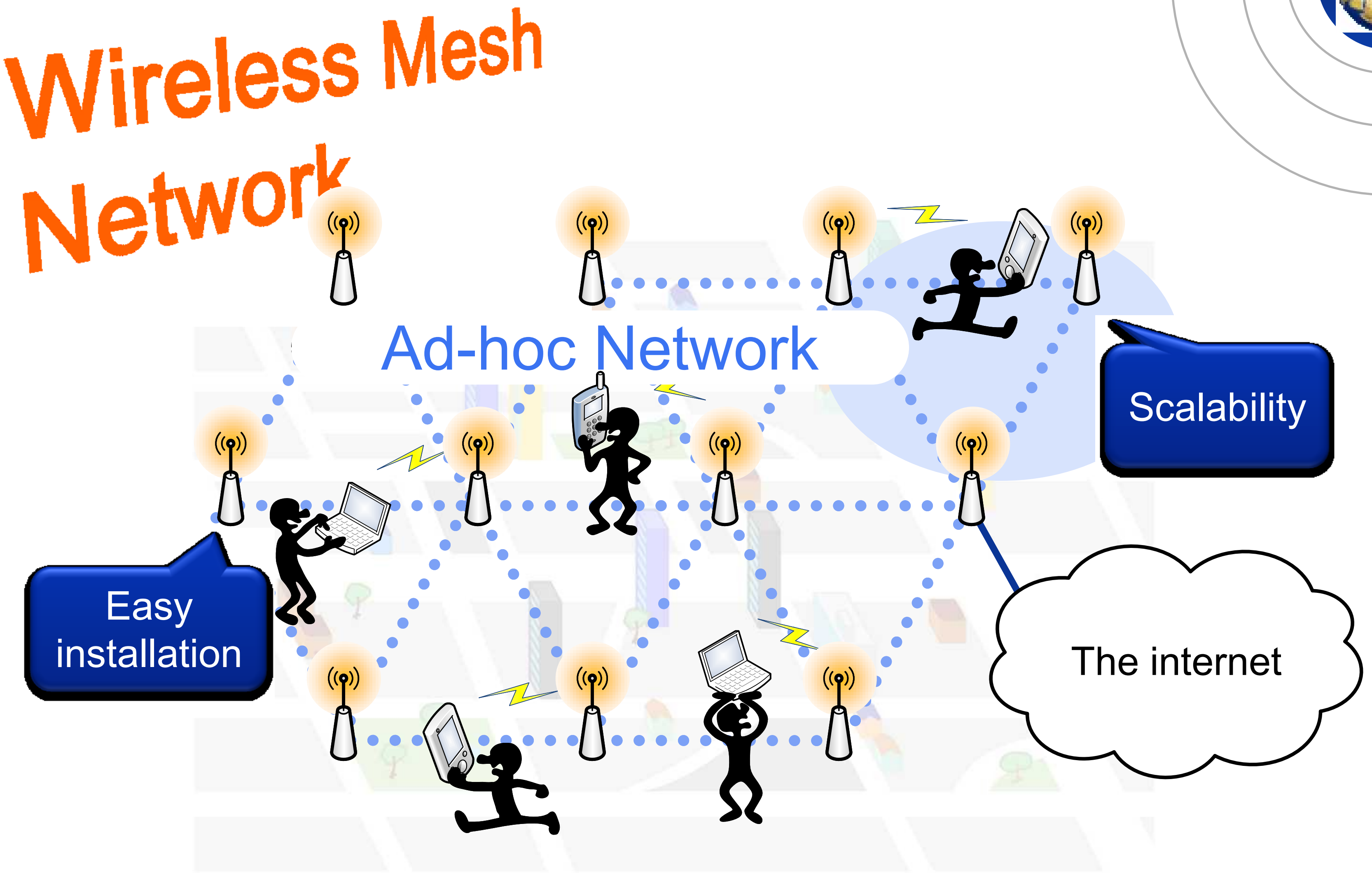
BACKGROUND –Wireless LAN-



Wireless LAN become popular due to location-free and Terminal mobility.

BACKGROUND –Wireless Mesh Network-

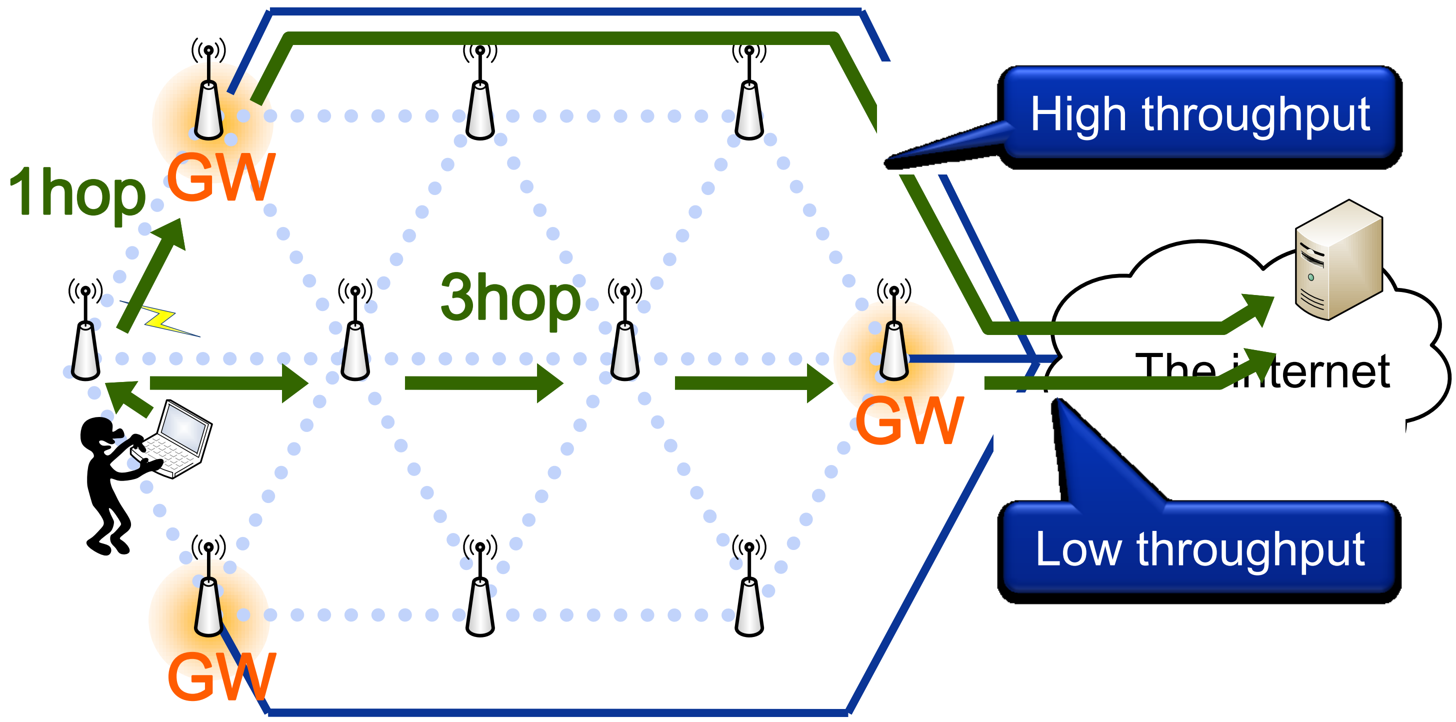


WMN is expected to grow due to easier installation and excellent scalability.

BACKGROUND –internet access-

Hop count should be minimized to get high throughput

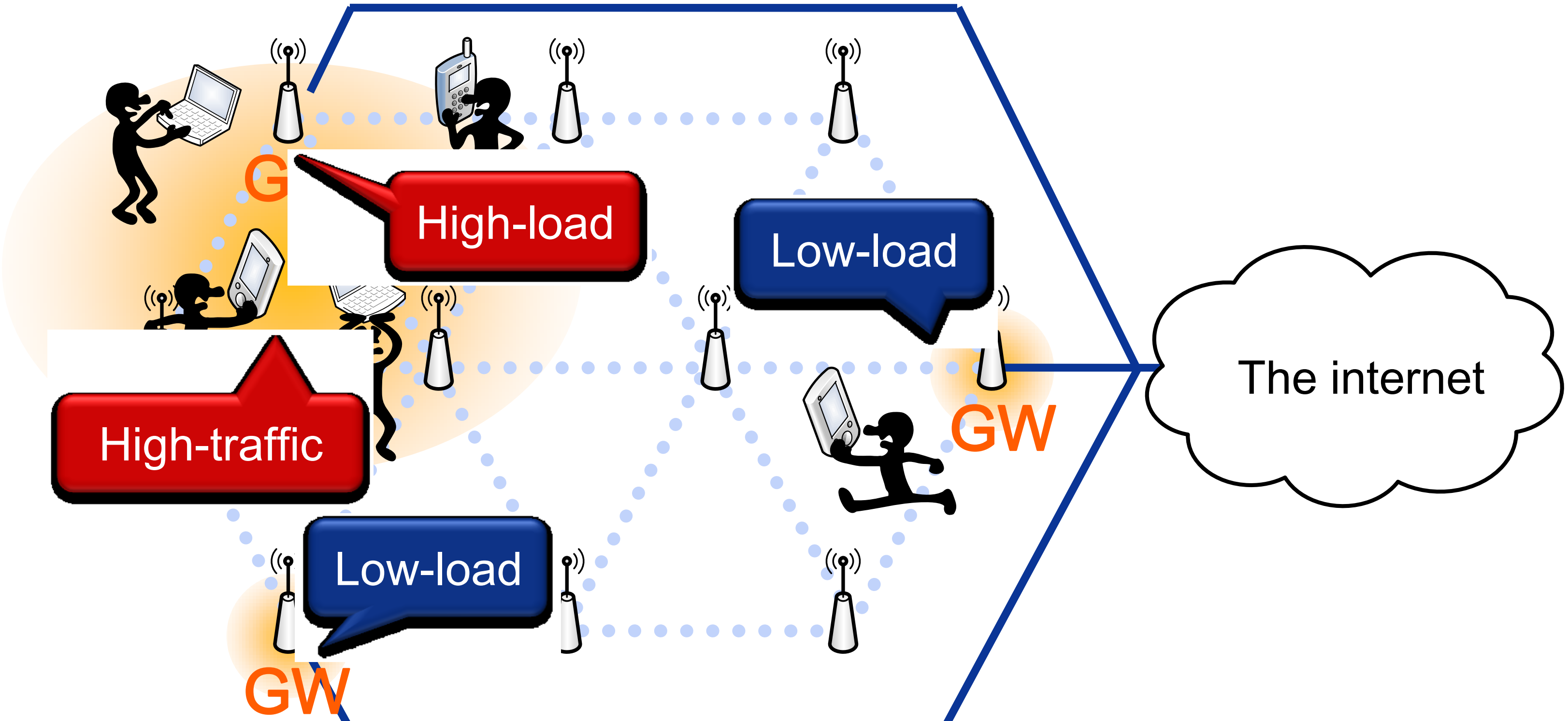
⇒ **Utilization of multiple gateways**



BACKGROUND –internet access-

When terminals concentrate around a specific GW

The Gateway uses up its bandwidth.
Other Gateways are not effectively used.



- **MGA：Multi Gateway Association**

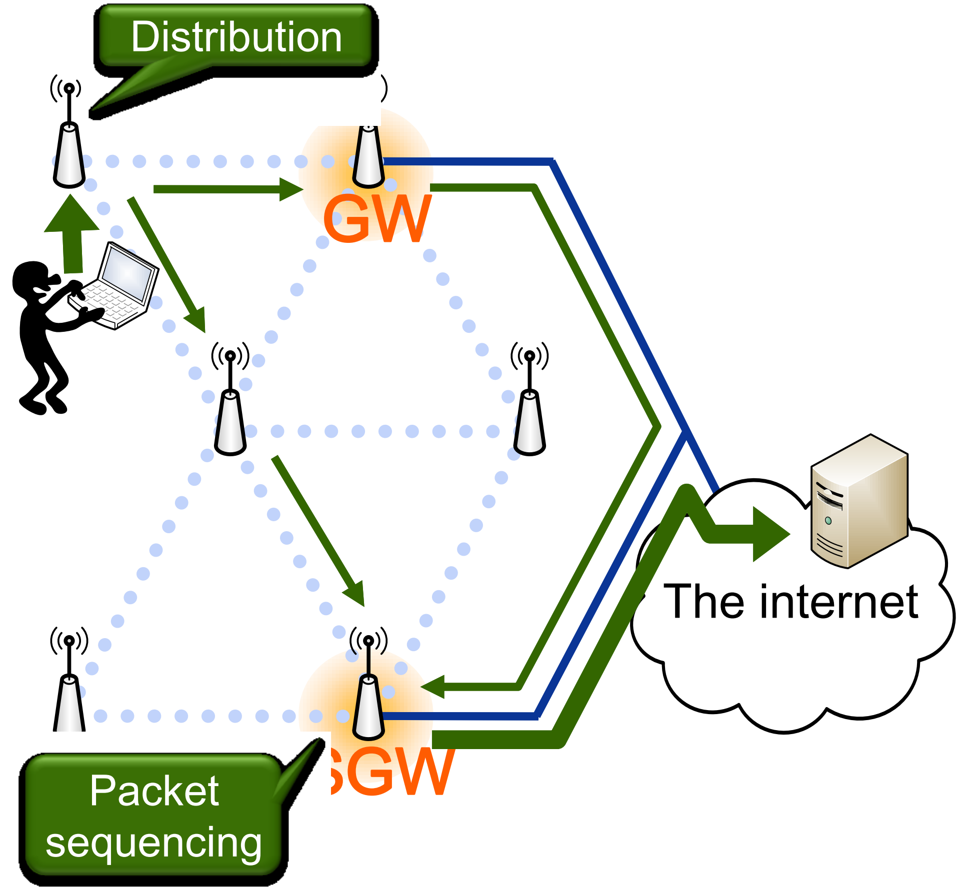
  The method that transmits packets to multiple GWs.

  – All APs calculate transmission ratio based on parameters such as hop count and the bandwidth of each route.

  – AP transmits packets to GWs based on the ratio.

  – Super GW aggregates packets and conducts packet sequencing, and transmits them to the exterior network.

➡ **Fairness use of GWs**

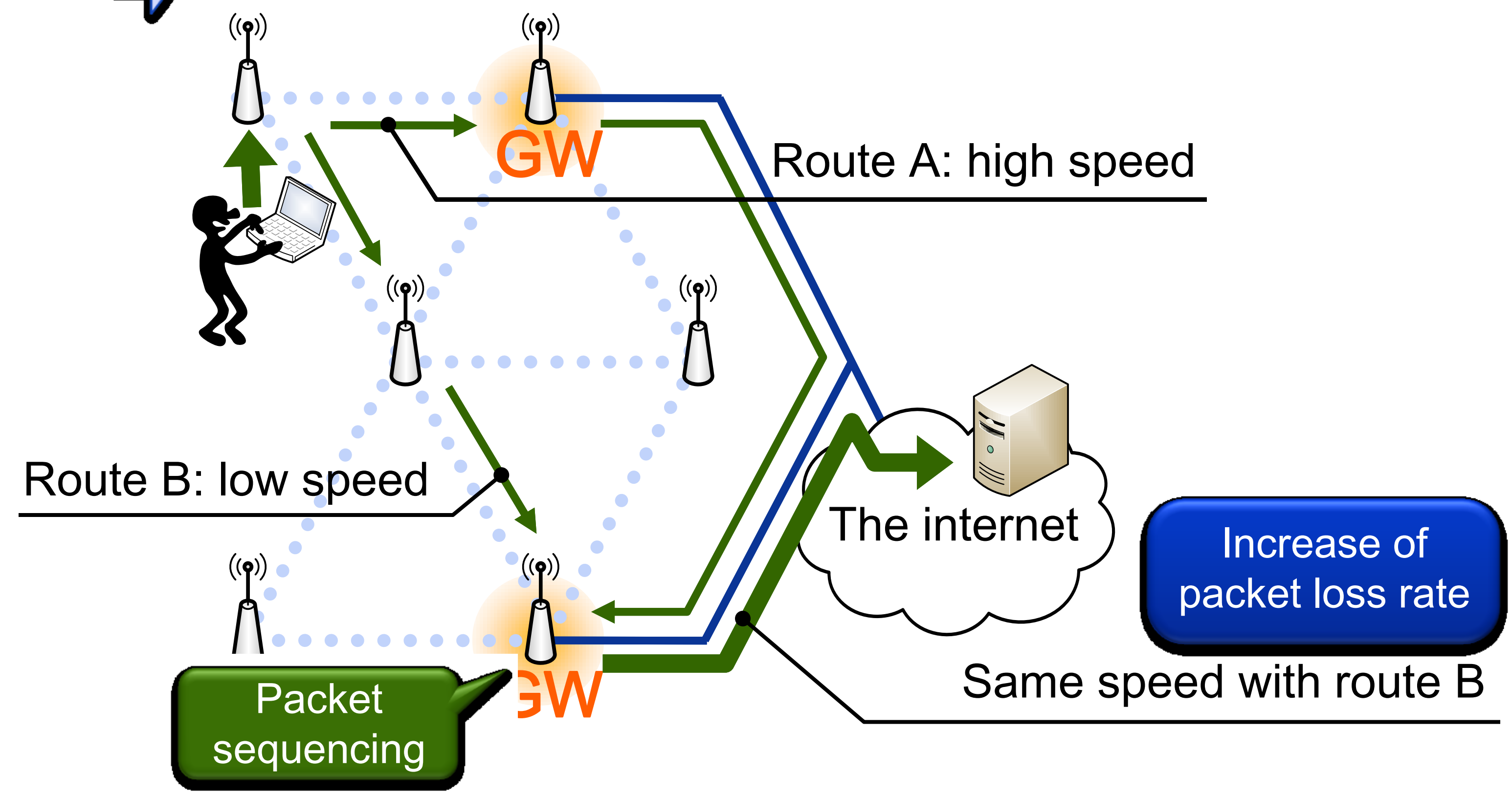


PROBLEM OF MGA

One session is divided to two or more routes.

⇨ Transfer speed depends on the route of the lowest speed due to packet sequencing.

⇨ TCP throughput gets lower.



PROPOSAL

- Utilization of multiple Gateways.
- Consideration TCP characteristics.

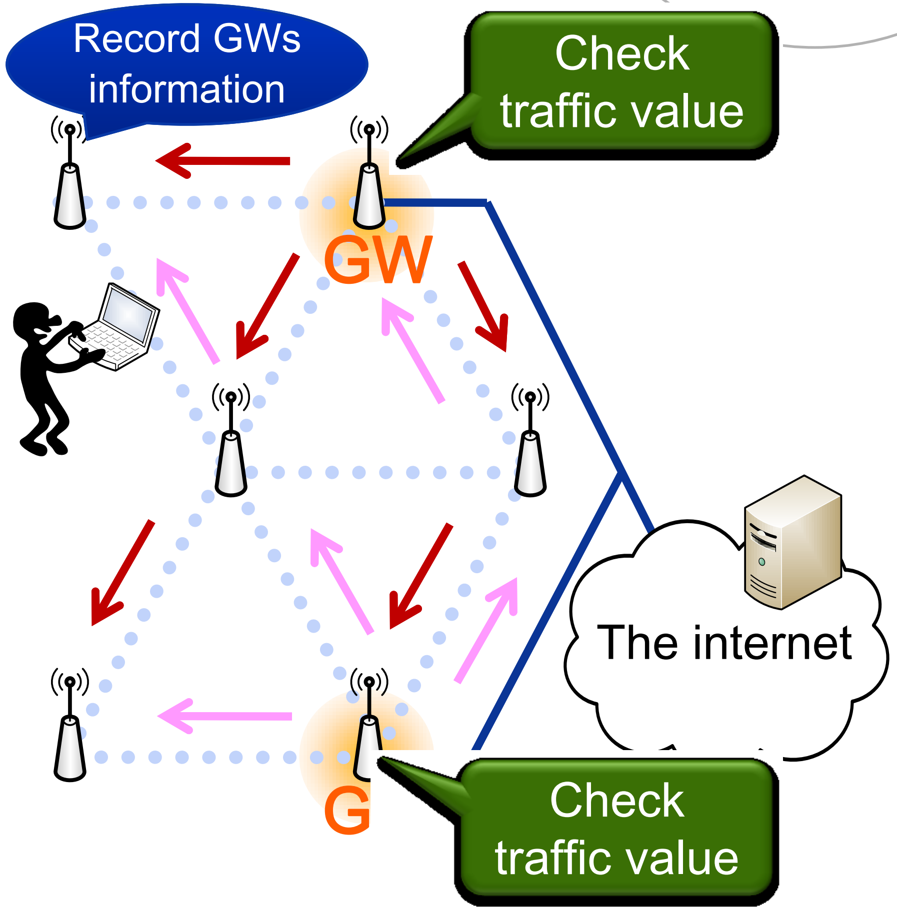
⇨ **Session distribution method**

Because the traffic is distributed on a session by session basis, delay of packet transfer is minimized, and the lowering of TCP transfer throughput is prevented.

PRINCIPLE OF PROPOSAL

Distribution of gateway information

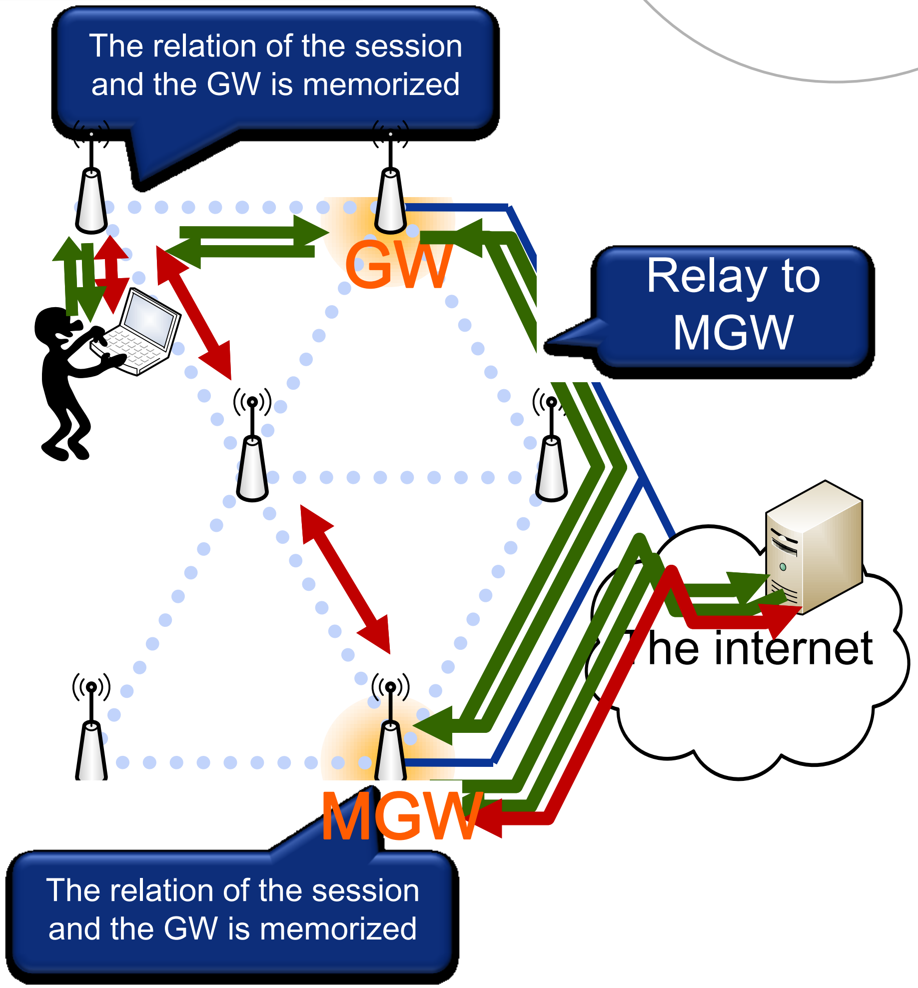
- GWs always check the volume of traffic around them.
- GWs flood messages that contains the traffic value and the number of hops to each AP.
- The number of hops is incremented each time when the message passes through an AP
- APs obtain the traffic condition of GWs and also the number of hops to GWs.



PRINCIPLE OF PROPOSAL

The method of session distribution

- The AP resolves a suitable GW according to the GW information.
- The AP memorizes the relation of session and the GW, and transmit packets.
- The GW relays packets to the master gateway.
- The master gateway memorizes the relation of the session and the GW, and transmits packets to exterior network.
- Subsequent packets of the same session trace the same route.



EVALUATION

- **Evaluation by simulations**
- **Modifications of ns-2**
  - Session distribution method (proposed method)
  - Packet distribution method

- **Traffic fairness and throughput**

  Evaluation of degradation of bandwidth fairness of the whole network by distributing a session by session.

  And Evaluation of throughput at the Master GW.

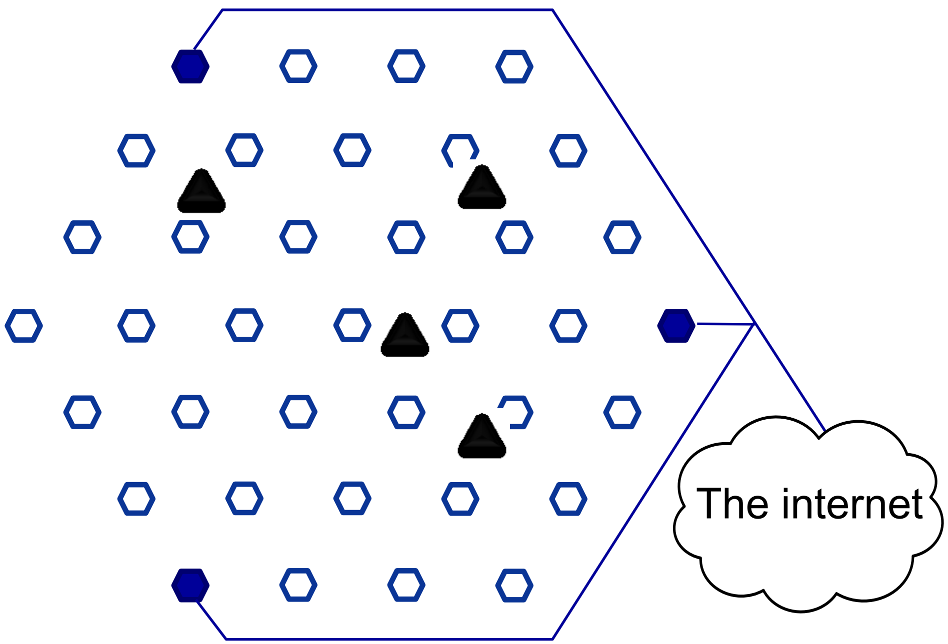
- **Influence to TCP communication**

  Evaluation of remediation of TCP communication throughput by distributing a session by session.

EVALUATION - traffic fairness and throughput -

- Comparison of bandwidth fairness of session distribution method with packet distribution method by giving the traffic.

Simulation parameters	
Radio-wave range of access	100m
Distance between APs	80m
Number of APs	37
Number of terminals	0-60
Type of communication	FTP(ext. - int.) Streaming(ext. - int.) VoIP(ext.-int. , int.-int.)
MAC protocol	IEEE802.11g
Field	860 x 580 m



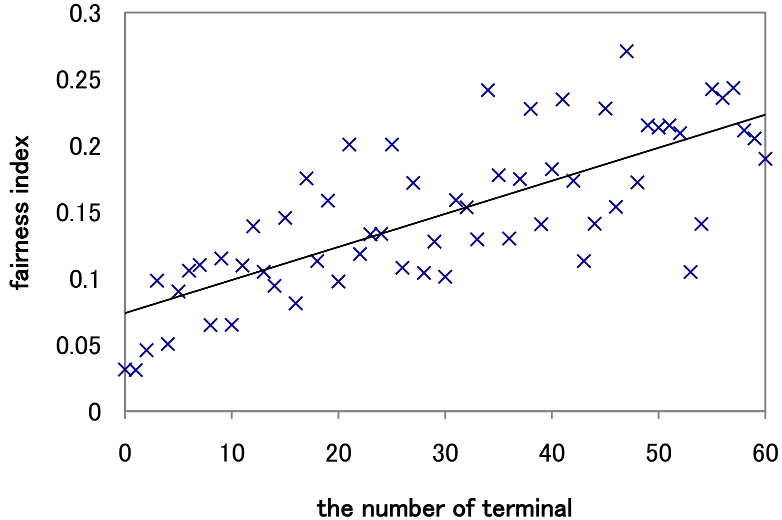
RESULT - traffic fairness -

Fairness Index

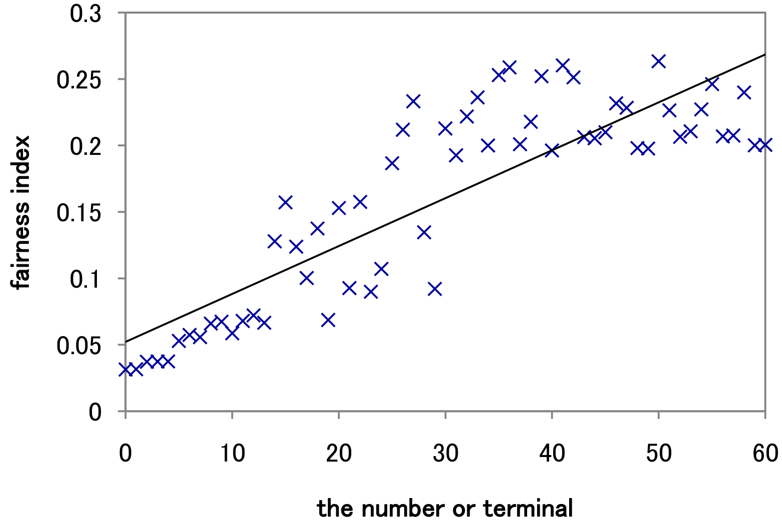
The closer to 1 the value of FI (Fairness Index) is, the higher the fairness is.
n indicates the number of APs and x_i indicates the transmission traffic of AP_i .

$$FI = \frac{(\sum_{i=1}^{n} x_i)^2}{n\sum_{i=1}^{n}(x_i)^2}$$

Session distribution method



Packet distribution method

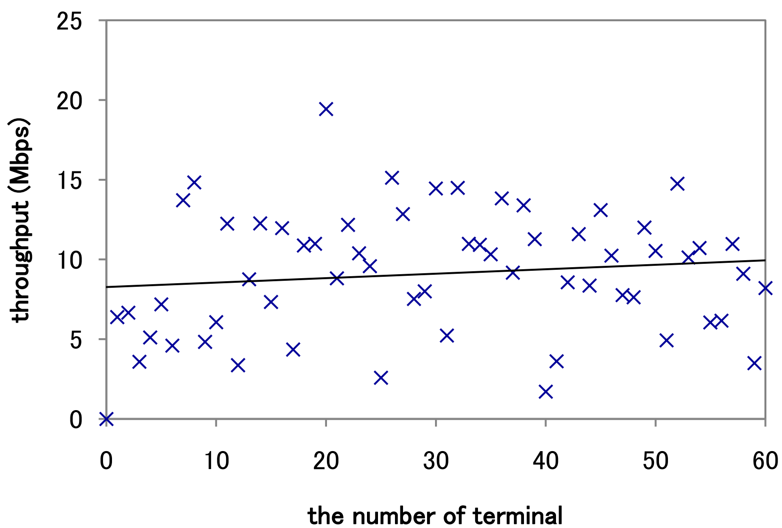


RESULT - traffic fairness -

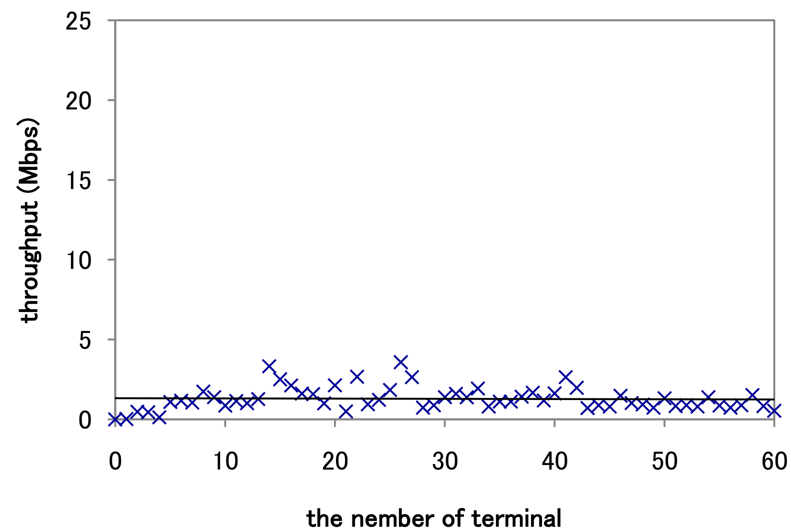
Throughput in Master GW

Measurement of the value of traffic through Master GW.

Session distribution method



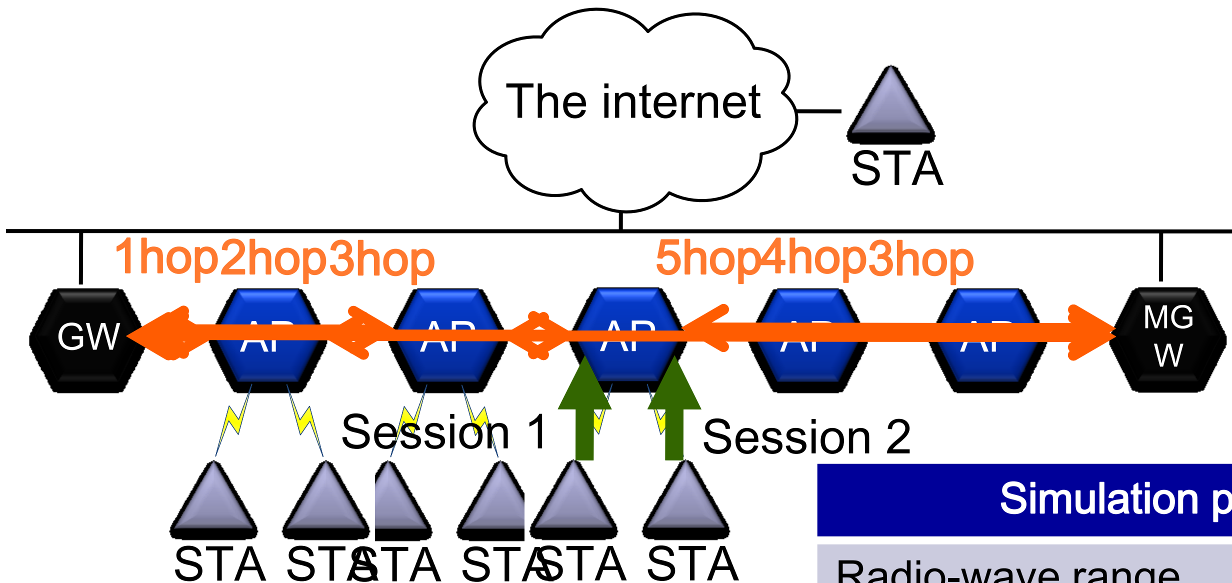
Packet distribution method



- Session distribution method has higher throughput in Master GW compared to the packet distribution method.

EVALUATION – effect on TCP -

Evaluation of the remediation of TCP throughput

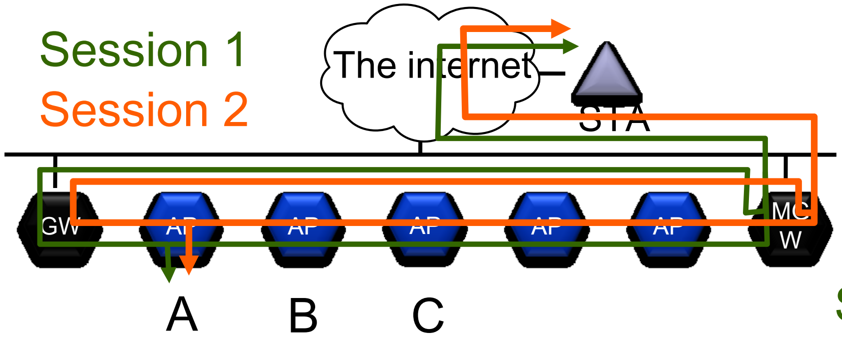


- Two TCP sessions are started from an AP to the exterior.
- Terminals changes its location and throughput is measured.

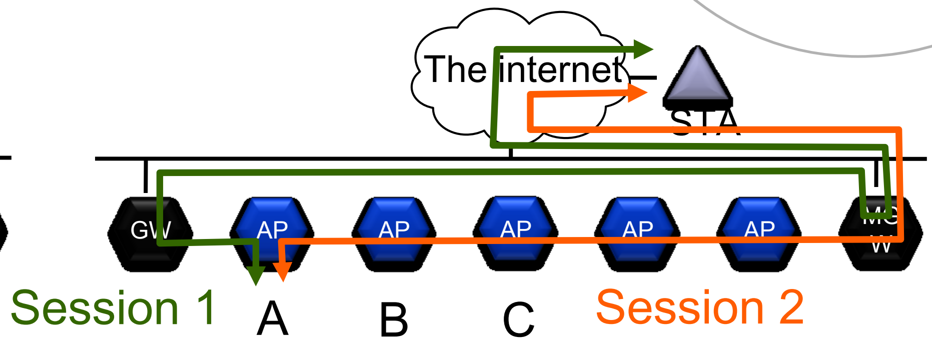
Simulation parameters	
Radio-wave range access	100m
Distance between APs	80m
Type of communication	FTP
MAC protocol	IEEE802.11g
Field	860 x 300 m

RESULT – effect on TCP -

Packet distribution method



Session distribution method



Location		A	B	C
Packet distribution method	Session 1	1.5	2.1	2.6
	Session 2	1.2	1.6	1.8
	Total	2.7	3.7	4.4
Session distribution method	Session 1	10.6	5.9	3.4
	Session 2	1.7	1.6	2.7
	Total	12.3	7.5	6.1

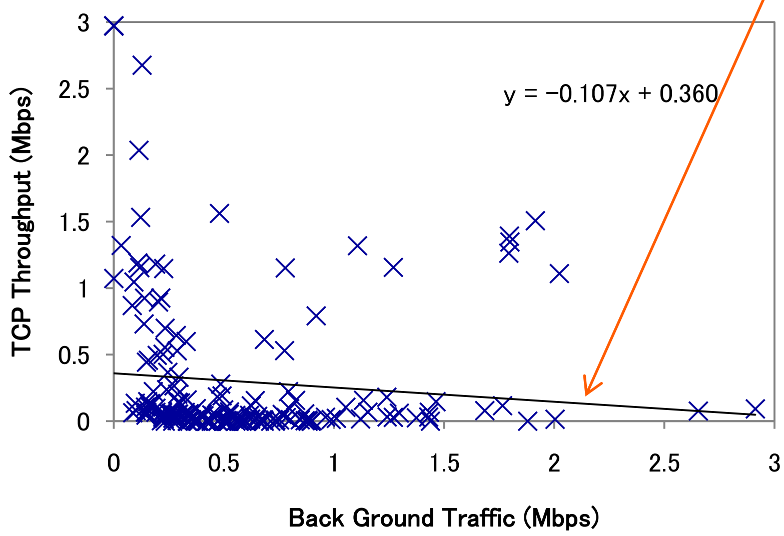
CONCLUSION

- **The proposal of session distribution method**
  - GWs flood the message of traffic of their and the number of hops to APs.
  - AP resolves a suitable GW according to GW information and distribute packets session by session.
- **Evaluation by simulation**
  - Session distribution method has higher efficiency in TCP communication.
  - Session distribution method does not cause any fairness problems
- **Future**
  - Proposed method has already been implemented.
  - Data collection using real devices.

Back up simulation of expected throughput

- We make up each traffic and hop count and throughput.
- We make first equation from relation of traffic and TCP throughput each hop count.

Example of 3 hops



First equation approximate curve

hop	First equation
1	$y = -0.68x + 3.50$
2	$y = -0.26x + 1.11$
3	$y = -0.11x + 0.36$
4	$y = -0.19x + 0.26$
5	$y = -0.12x + 0.18$