Proposal for Wireless Mesh Network that Realizes Seamless Handover and Its Simulation Results

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***Abstract*— Wireless Mesh networks have an advantage of building backbone infrastructure easily, where access points, which have been conventionally connected by wired LANs, are connected by an ad-hoc network using Wireless LANs. However, the Wireless Mesh Network still has various problems such as the realization of a seamless handover, the securing of a communication bandwidth, and the selection of the most suitable routing protocol. WAPL (Wireless Access Point Link) which we propose in this paper can solve all these problems. Namely, WAPL enables a constant seamless handover. It does not give much influence on the traffic. It can also select ad-hoc routing protocols freely. To realize a seamless handover, WAPL is aware of communication routes all the time and sends an advertising message that reports its handover in unicast mode. To reduce the traffic of control messages, it generates mapping information, which is the relation between access points and terminals on demand. In WAPL, the function generating mapping information is completely independent of an ad-hoc routing protocol. In this paper, we implemented WAPL in network simulator ns-2, and compared it with the existing methods. We succeeded in showing the features of WAPL quantitatively.**

I. Introduction

Researches on Wireless Mesh Networks (WMNs) are being attracted much attention these days. WMNs make it easy to build backbone infrastructure by connecting APs (Access Points) through an ad-hoc network using wireless LANs. R&D on WMNs has been conducted by various organizations[1][2][3], but since they all adopt essentially different methods, there is almost no compatibility among them. Accordingly, IEEE Task Group 802.11s has been proceeding with the standardization of a WMN[4]. The basic concept of the WMN is that APs are inter-connected by an ad-hoc network and each AP and its terminals are connected to the AP in infrastructure mode. In a WMN, APs need to know somehow the mapping information indicating a list of correspondent terminals connected to an AP. A packet sent by a certain terminal is forwarded to a destination terminal via a number of APs referring to the a mapping information in APs. However, a WMN has several drawbacks compared with a wired network. For instance, communication by a WMN is not as stable as a wired network; suitable ad-hoc routing protocols are different depending on the user environment. Realization of a seamless handover is also an issue. The fact that stable communication cannot be ensured in a WMN is due to that the connections among APs are made by an ad-hoc network, where flooding of a packet may not carried out properly. In the case of existing WMNs, routing protocols of ad-hoc networks and the administration of the AP/terminal mapping information are integrated, and as a result, it is not possible to replace routing protocols. Thus, it has a constraint of not being able to properly adjust itself to the user environment. Moreover, although realizing a seamless handover is important in avoiding communication interruption while a terminal is moving, the subject of the handover is not dealt with in IEEE802.11s[5]. As the studies of WMNs to realize a seamless handover, SMesh[6] and iMesh[7] have been proposed. In the case of SMesh, it is realized by the way that a route for a packet is doubled at the time of a handover,however the terminal needs to be operated in an ad-hoc mode, which is not suitable for our purpose. In the case of iMesh, although it is realized by the way that packets are buffered by an AP when a terminal is moving, there is a rather high possibility of a handover message failure, because the message is reported by flooding.

In order to solve these problems, we propose a new wireless mesh network ”WAPL” (Wireless Access Point Link). In WAPL, APs constantly monitor communications in the neighboring area (within the range of 1 hop) and acquire information about the terminals of both ends of communication and the APs to which the terminals belong. Based on this information, the AP/terminal mapping information can be renewed on receiving a control message sent by unicast transmission that is more stable than flooding at the time of a handover of the terminal. Also, in a WAP, since the initial AP/terminal mapping information is generated on-demand, control traffic is minimized. Furthermore, the module which generates AP/terminal mapping information and the ad-hoc routing module are independent of each other; it is possible to select any routing protocols freely according to the user environment. In this paper, we report the effectiveness of WAPL, which were identified by the simulation.

II. EXISTING TECHNOLOGIES

IEEE802.11 formed a Task Group s and is proceeding with the standardization of the wireless mesh network. But, IEEE802.11s has not studied the problem associated with the seamless handover yet. Meanwhile, iMesh and SMesh have been proposed as technologies to realize the seamless handover. We explain the outline of IEEE802.11s and iMesh together with their associated problems compared with our WAPL. We exclude SMesh from our explanation, because in this technology, terminals need to be operated in ad-hoc mode. That makes this technology unsuitable as a target of the review in this study, as we assume that terminals are operated in an infrastructure mode in WAPL.

A. IEEE802.11s

In IEEE802.11s, an access point which is connected by wireless is called MAP (Mesh Access Point). In IEEE802.11s, HWMP (Hybrid Wireless Mesh Protocol) is used to generate the routing table among MAPs and MAP/terminal mapping information. HWMP is implemented at the MAC layer and performs the same operation as ad-hoc routing protocols by using MAC addresses instead of IP addresses.

Although HWMP basically performs a reactive-type routing by RM-AODV (Radio Metric AODV) that is based on AODV (Ad hoc On-Demand Distance Vector)[8], it can perform a pro-active-type routing by forming a tree-type path, when a fixed-type network is formed. In RM-AODV, when a terminal starts communication, MAP, as a proxy of the terminal, advertises route request messages to other MAPs. Upon receiving the request message, the MAP, which is associated with the destination terminal, sends back a reply message as a proxy of the destination terminal. Through this exchange of messages, a route from the source terminal to the destination terminal is established. A data packet is forwarded through the MAPs.

When the terminal moves during communication, a route search is performed again, but handling of packet delivery before the route is correctly reestablished has not been studied yet. Though handover methods have been separately studied by IEEE802.21[9], the connection among APs based on the ad-hoc network is beyond the scope of its study.

B. iMesh

iMesh adopts modified OLSR (Optimized Link State Routing)[10] as a method to generate AP/terminal mapping information. When a terminal associates with an AP, the AP initiates to flood expanded HNA messages. In the HNA message, terminal address information is included, and APs which receive this message generate AP/terminal mapping information. At the time of a handover, the same process is performed. Fig. 1 shows the sequence of message exchange at the time of the handover. Here, the AP to which the moving terminal has associated before the handover is called ”old AP”, the AP to which the moving terminal associates after the handover is called ”new AP”, and the AP to which the corresponding terminal associates is called ”source AP”. When the terminal moves, it sends a deauthentication message to the old AP and a reassociation message to the new AP. The new AP, which received the reassociation message, starts to flood the expanded HNA messages. When the expanded HNA message reached the source AP, the communication route is renewed so that the message may be forwarded to the new AP. During this operation, packets transmitted from the corresponding terminal are buffered in the old AP, and are forwarded to the new AP when the expanded HNA message is received. In this method, all messages normally reach the moving terminal. However, the flooding is an operation of forwarding of a MAC broadcast frame repeatedly so that messages can be advertised throughout the network, and any RTS/CTS control is not performed for the MAC broadcast. Therefore, if neighboring APs, which are not aware that the broadcast is being performed may start transmission, the broadcast packet may be corrupted. For this reason, in the situation where the background traffic exists, the rate of unsuccessful broadcast becomes high and a handover tends to end in failure. As a relief measure to deal with that kind of situations, the same message is flooded periodically with an interval of several seconds even after the completion of the reassociation with the new AP, Therefore it takes some time before the communication is recovered. Also, the influence on the traffic cannot be neglected when the system scale becomes large.

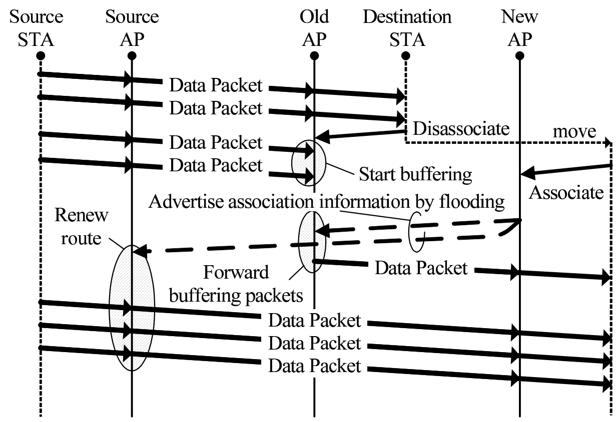

Fig. 1. The sequence of handover process in iMesh.

III. A PROPOSAL OF WAPL

A. Basic concept of WAPL

In WAPL, an AP which is connected by a wireless LAN is called a ”WAP” (Wireless Access Point). WAPL adopts an on-demand method where WAP/terminal mapping information is generated at the starting time of communication. In the WMN environment, the on-demand method adopted by WAPL has an effect of reducing control traffic, because it is assumed that there are a number of terminals which are connected to WAP but are not engaged in communication. For a generation of the routing tables among WAPs, the ad-hoc routing protocol is used as it is. WAP/terminal mapping information in WAPL is independent of the routing table, and is retained in a

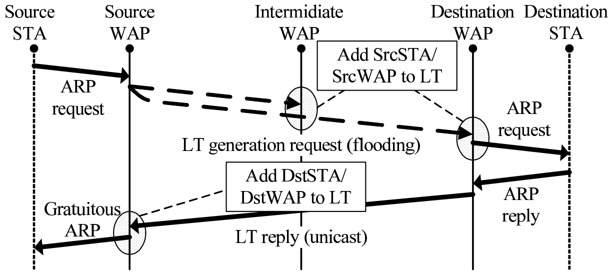

Fig. 2. The sequence of LT generation process in WAPL.

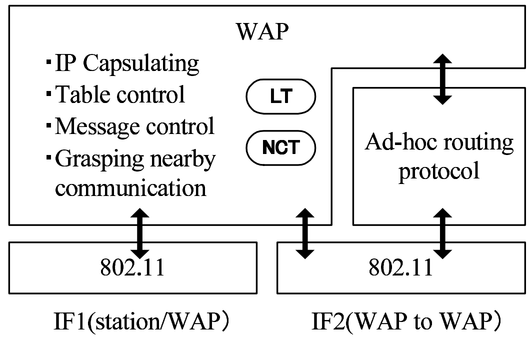

Fig. 3. Architecture of WAPL.

table called "LT" (Link Table). The LT is renewed by an ARP processing as a trigger at the time when a terminal initiates communication. Fig. 2 shows the sequence of the LT generation. Upon receipt of an ARP request from a terminal, a WAP advertises it to other WAPs by flooding a LT generation request message. This operation is independent of the ad-hoc routing, and the renewal of the LT is realized by repeating the broadcast by the LT generation module. In the LT generation request message, the IP address of the destination terminal, the IP address of the source terminal, and the MAC address are described. All the WAPs which have received the LT generation request message, records the relationship between the IP address of the source terminal and the source WAP. The WAP, which detected that the destination terminal exists under itself, returns an LT response message to the source WAP by unicast transmission. In the LT response message, the IP addresses and the MAC address of the destination terminal and the source terminal are described. The source WAP, upon receiving the LT response message, records in its LT the relationship between the destination terminal and the destination WAP. Through the above process, the AP/terminal mapping information of the other terminal is generated in the WAP. The data packets thereafter are encapsulated with the IP addresses of WAPs and forwarded to the destination terminal.

B. Architecture of WAPL and its merit

Fig. 3 shows the architecture of WAPL. In WAPL, the module which maintains the AP/terminal mapping information and the module for the ad-hoc routing protocol are completely separated and thus, ad-hoc routing protocols can be selected freely. Because of this feature, we can think the characteristics of the connections among terminals and the characteristics of the connections among APs separately, and we are able to establish an efficient mesh network suitable for the user environment. In the wireless mesh network, it is expected that there are many terminals which are not engaged in communication. Therefore, if AP/terminal mapping information is generated by periodic advertisements, there is a concern that the amount of control messages becomes quite large. Thus, an on-demand method applied by WAPL is suitable for the generation of AP/terminal mapping information.

In the meantime, as for the routing method among APs, the most suitable method varies depending on the user environment. As the user environment, two cases are considered; namely, one case is that a permanent communication network like a public communication network and the other case is that a temporary communication network, such as the one created at the time of a disaster occurrence, or in an event site. In case of the public communication network, there is no movement of APs, and also electric power can be supplied. In the case of the temporary communication network, however, APs are assumed to be moving and also electric power source may not be necessarily ensured. In WAPL, selection of a specific ad-hoc routing protocol is possible. There is also an advantage that when in the future new routing protocols are proposed or when an improvement of the same protocol is made, such protocols can be applied to WAPL just as they are.

C. Realization of a seamless handover

1) Monitoring nearby WAP communications: In WAPL, in order to ensure the handover notification at the time of terminal moving, the handover is notified to the old WAP and the source WAP in unicast transmission. Each WAP needs to have created a table in advance that stores information concerning terminals performing communication in the vicinity. The table is called the "nearby-communication table" . Fig. 4 shows the generation method of the nearby-communication table. Each WAP constantly monitors communication packets transmitted by other WAPs in the vicinity in promiscuous mode. Each WAP acquires the destination and source WAPs from the IP headers of the packets addressed, and the IP addresses and MAC addresses of the destination and the source terminals from the encapsulated MAC/IP headers, and records them in its nearby-communication table. Through the above process, each WAP can acquire the communication situation of other WAPs in the neighboring area.

2) Notification of the handover: Fig. 5 shows the process for the handover notification at the time when a terminal moves. The old WAP starts buffering after receiving a deauthentication message from the moving terminal. The new WAP, upon receiving a reassociation message from the terminal, refers to the nearby-communication table from the MAC address of the terminal and judges whether it is in the middle of communication. If there exists the record of a IP address of the

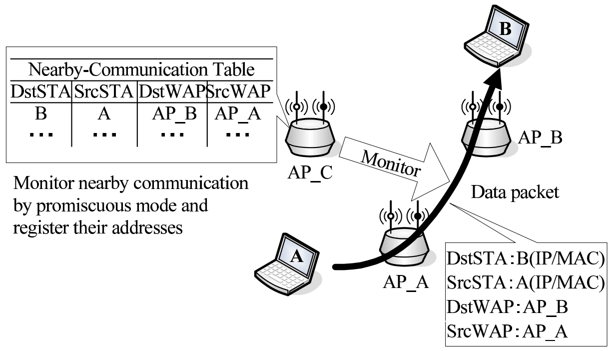

Fig. 4. The method of grasping neighbor communication.

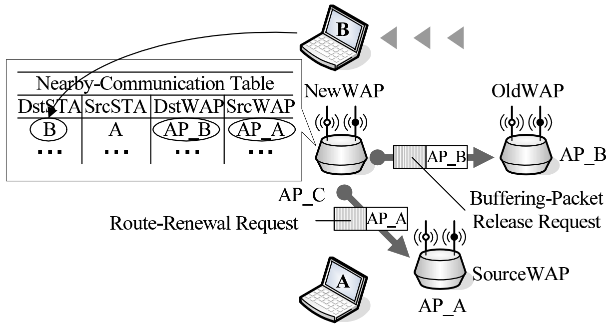

Fig. 5. Handoff notification.

reassociated terminal, the new WAP starts a handover process. The new WAP extracts the IP address of the old WAP and the IP address of the source WAP from the near-by communication table, and transmits a release request message to the old WAP and a renewal request message to the source WAP. Both the old WAP and the source WAP return response messages. If no return message is sent back within a certain period of time, the new WAP sends the request messages again. The old WAP, upon receipt of the release request message, forwards the buffered packets to the new WAP. The source WAP, upon receiving the renewal request message, renews its LT, and the handover is completed. In WAPL, because a control message is notified by unicast transmission, the reliability of the packet delivery is quite high, and the retransmission control is also possible because the source WAP is specified.

IV. Evaluations

In order to show the effectiveness of WAPL, iMesh and WAPL are evaluated and compared by ns-2 (network simulator-2)[11]. The evaluation items are as follows;

(1) the non-arrival rates of handover notification,
(2) the influence of the expanded HNA messages of iMesh on the traffic,
(3) the influence of the LT generation messages of WAPL on the traffic.

Since ns-2 does not have the functions of wireless LAN infrastructure mode, the connection between APs and terminals are realized by adding functions to the IEEE802.11 module. The functions include sending beacons, judging the AP departures and reassociations by the strength of radio waves, and processing disassociations as well as reassociations. While in the WMN, an AP needs to have two interfaces of an infrastructure mode and an ad-hoc mode, a simulation environment is realized by directly linking the internal modules of the two interfaces. The same channel is employed for all communication between APs and terminals.

A. Comparison of the non-arrival rates of the handover notification

The non-arrival rates of the control messages transmitted to the new AP and the source AP at the time of a handover were evaluated for both WAPL and iMesh. 24 APs were set in the simulation field, and two terminals were communicating with each other in both directions. One terminal was fixed and another terminal moves constantly between two APs. For communication, we assumed VoIP, two terminals transmit packets of 172 bytes each in UDP with the rate of 50 times per second. In order to evaluate the non-arrival rates under different background traffic loads, several terminals were set at random in the simulation field to generate the background traffic, and a part of two terminals performs UDP communications. The position of the terminals and the communication pair were selected at random and changed periodically. In order to change the background load conditions, the background traffic was adjusted by changing the transmission rates while fixing the data size as 500 bytes. In order to evaluate the influence of the number of hops from the source AP to the destination AP, the conditions were changed by moving the position of the fixed terminals so that the number of the hops to the moving terminal becomes between 1 and 4. During one simulation run, about 1,000 times of handovers were performed and the non-arrival rates were measured.

The non-arrival rates of the handover notifications to the old AP are shown in Fig. 6, and the same rates to the source AP are shown in Fig. 7. The horizontal axis is the background traffic sent by a terminal. The non-arrival rates to the old AP in iMesh increase as the increase in the background traffic, and it reaches about 10% when the traffic of the background load terminal is 1.25 Mbps. The non-arrival rates to the source AP vary depending on the number of hops, and with 4 hops, the non-arrival rate reaches around 13% when the background load is 1.25 Mbps.

When the number of hops increases, the collisions of the expanded HNA messages increase and thus, the non-arrival rates become higher. To the contrary, in the case of WAPL, the non-arrival rates are 0% thanks to the effect of using the unicast transmission. In this way, we can see that the seamless handover is realized in the case of WAPL.

B. Influence of the expanded HNA messages on the traffic

In iMesh, as each AP generates the AP/terminal mapping information for the entire system, it floods the expanded HNA messages periodically. In this message, information of the terminals not active in communication is also included. Since

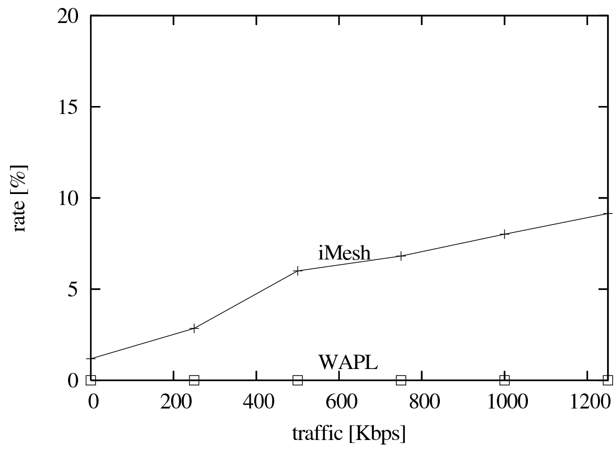

Fig. 6. Non-arrival rates of Release Request.

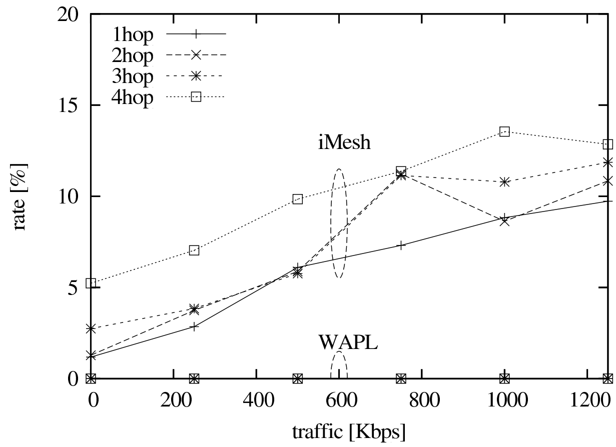

Fig. 7. Non-arrival rates of Renewal Request.

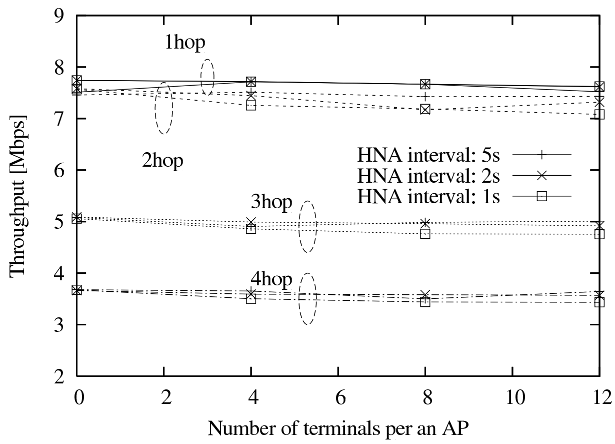

Fig. 8. Throughput in 38 access points.

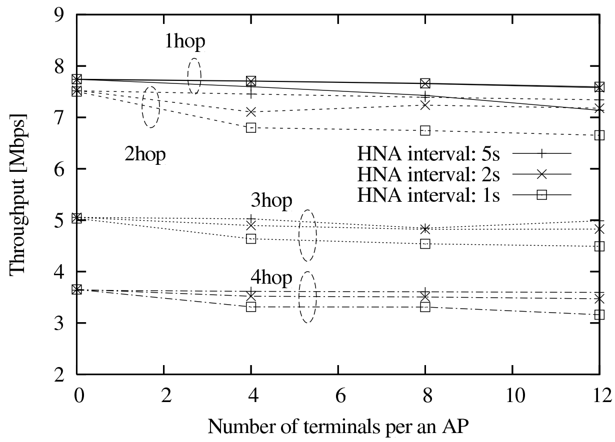

Fig. 9. Throughput in 52 access points

it can be expected that there are a number of terminals on the network which are not active in communication, the influence of the flooding on the general communication throughput was evaluated. Several APs were set in the simulation field with an equal interval, and set several terminals at random which do not perform communication. Then, two terminals are set for the purpose of throughput measurement, and we measured the throughput of FTP communication of 100 seconds for various conditions. The conditions, such as the number of APs, the number of terminals, the number of hops, and the transmission intervals for the expanded HNA messages, were changed. As for the conditions, the numbers of APs were set to 38 and 52 units; the number of the terminals was 0, 4, 8, and 12; the number of hops was 1 to 4; the interval of the expanded HNA messages was 1, 2 and 5 seconds.

Fig. 8 shows the throughput for the case where the number of APs is 38, and Fig. 9 shows the throughput when the same number is 52. When the interval of the expanded HNA messages is long and the terminal density per AP is small, the difference in the throughputs is not clear compared with the case that the number of the terminal is zero, but it can be seen that when the interval of the expanded HNA messages is short and the terminal density is large, the decreasing rate of the throughput of general communication becomes high.

From Fig. 9, where the HNA transmission interval is 1 second, and the number of hops is 2, the throughput decreases about 10 % when the number of the terminals increases from 0 to 12. These effects are attributable to the data size of messages and the number of packets. If the number of the terminals belonging to the same AP is large, the data size of the expanded HNA messages becomes long, and if the transmission interval of the expanded HNA messages becomes short, the number of the packets increases. Also, if the number of APs becomes large, the number of the transmitting sources of the expanded HNA messages becomes large, and as a result, the number of the HNA messages in the entire network becomes large. From this fact, it is considered that in the case of iMesh method, the size of network and the number of connecting terminals are restricted in the case of iMesh method.

C. Influence of the LT generation request messages on the traffic

In WAPL, since the flooding for a LT generation is executed at the time when communication between terminals begins,

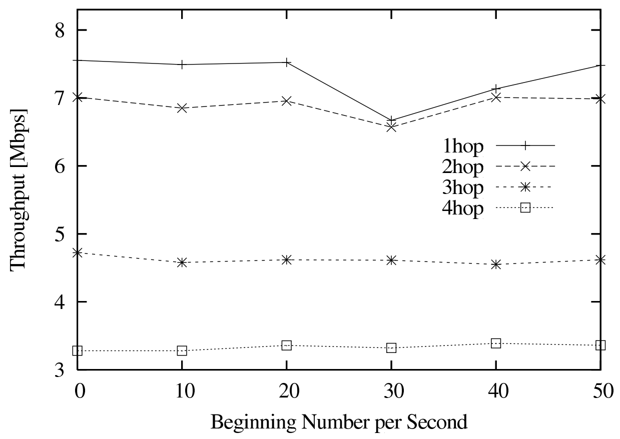

Fig. 10. Throughput vs. frequency of the beginning of cummunication.

there is a possibility that the control messages become a burden to the network if the frequency of the beginning of communication is high. Thus, the simulation evaluating its influence on the throughput was evaluated, by changing the frequency of communications. 52 APs were set in the simulation field with an equal interval, and 200 terminals were set at random. By changing the communicating terminals periodically on an at-random basis, the traffic by communication-initiating messages are generated. After the start of communication, both terminals transmitted UDP packets of 172 bytes in both directions 50 times per second. In order to keep the number of the sessions constant a new session was always initiated after terminating one session.

It is assumed that the communication frequency is 50 times per second, which corresponds to the case where each terminal is supposed to initiate and terminate a session every 4 seconds. This is a quit severe condition as the frequency of communication. Under these conditions, simulations were conducted for different number of hops, where the two terminals which had been installed for the purpose of measuring the throughput perform FTP communication for 100 seconds and its throughput was measured.

Fig. 10 shows the result of our simulation. It can be seen that the throughput does not change for the case where the frequency of communication is zero to 50, for all hop numbers. This means that the WAPL method which generates the LTs on demand does not give any influence on general communications.

V. Conclusion

We proposed WAPL as a new type of Wireless Mesh Networks. In case of WAPL, we can keep the non-arrival rate of the handover notification messages at almost 0% , by sending the handover notification messages by unicast transmission. The exchange of AP/terminal mapping information gives almost no effect on the traffic, because it is done only at the time of starting communication and the time of a handover. Also, in WAPL, the ad-hoc routing protocol and the WAP/terminal mapping generation function are completely independent of each other. Thanks to this fact, we can select the ad-hoc routing protocol most suitable to the user conditions. By conducting a simulation, we showed that WAPL can realize a seamless handover. Moreover, we showed that the control messages of WAPL give almost no effect on the throughput of communications.

As the next step, we will conduct simulations under various conditions including the application to the communication environment at the time of a disaster and evaluate suitable ad-hoc routing protocols. Furthermore, we are going to construct and operate test beds using real devices and perform evaluations.

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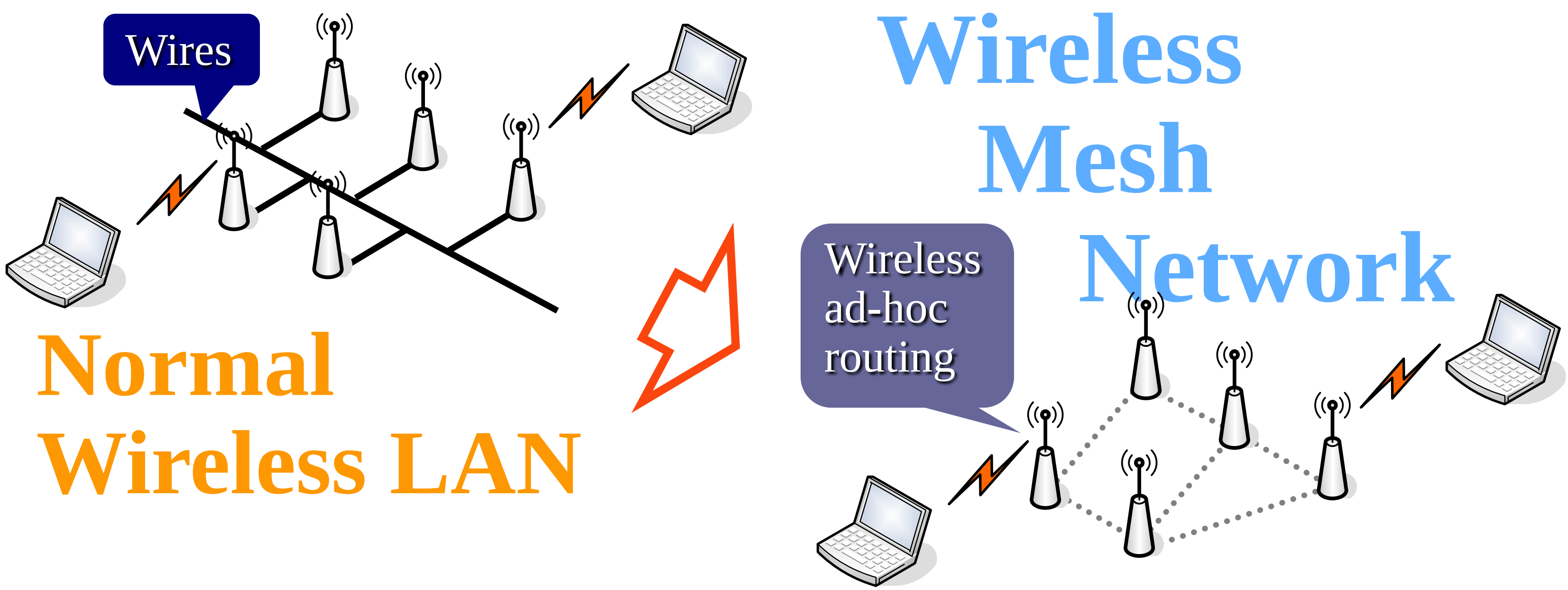
BACKGROUND

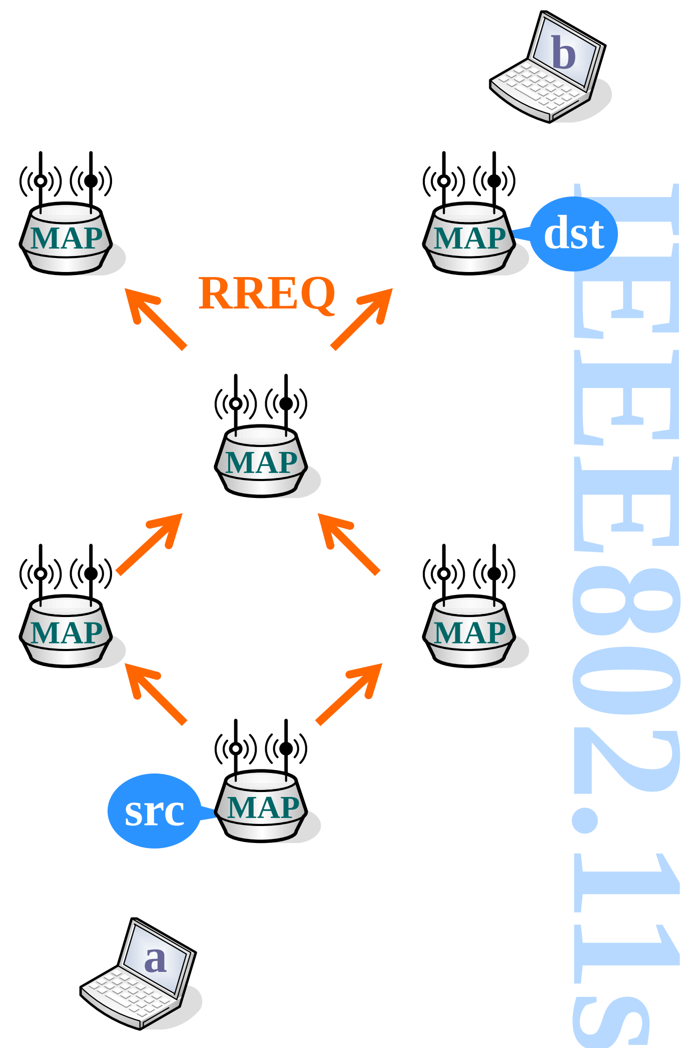
- **The Spread of Wireless LAN.**
  - Location freedom without using wires.
  - Terminal mobility.
- **Further request of the expansion of communication area.**



WMN can construct and expand wireless range easily.

EARLY STUDY - IEEE802.11s -

- **Mesh Protocol**
  - An original reactive-type protocol: RM-AODV
  - Switching to proactive-type is possible.
- **RM-AODV(mapping &routing)**
  - When a station transmits a packet, the source MAP searches for routes to the destination station with the advertisement of RREQ as a proxy of the source station.
  - Destination MAP unicasts RREP
  - A route between the stations is established in MAPs.
- **Handover - - - Out of scope.**



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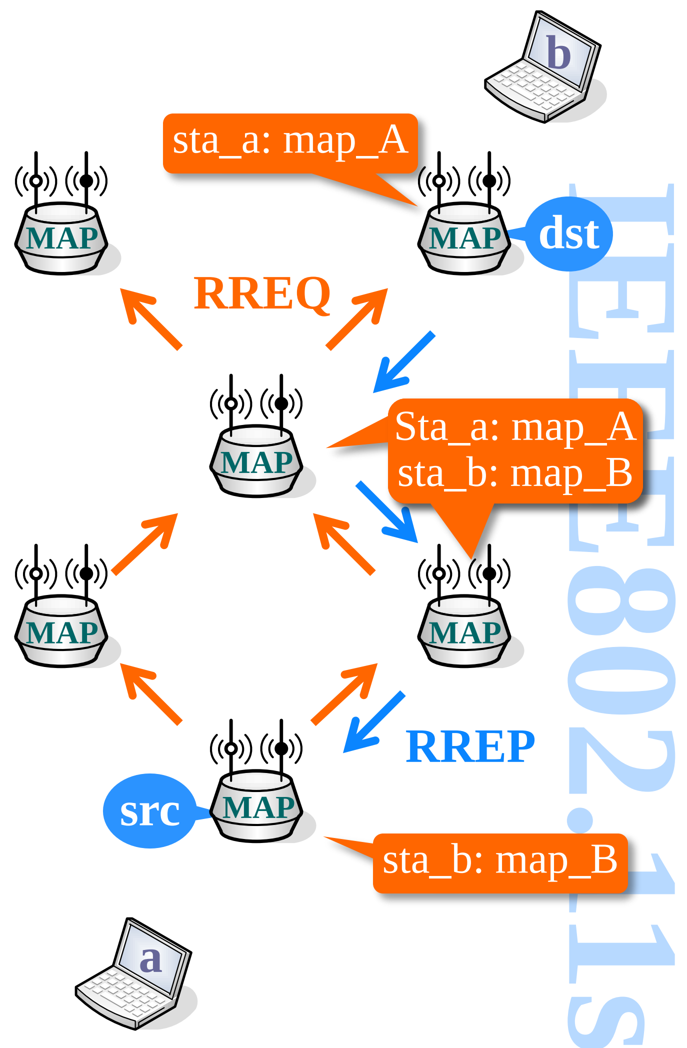

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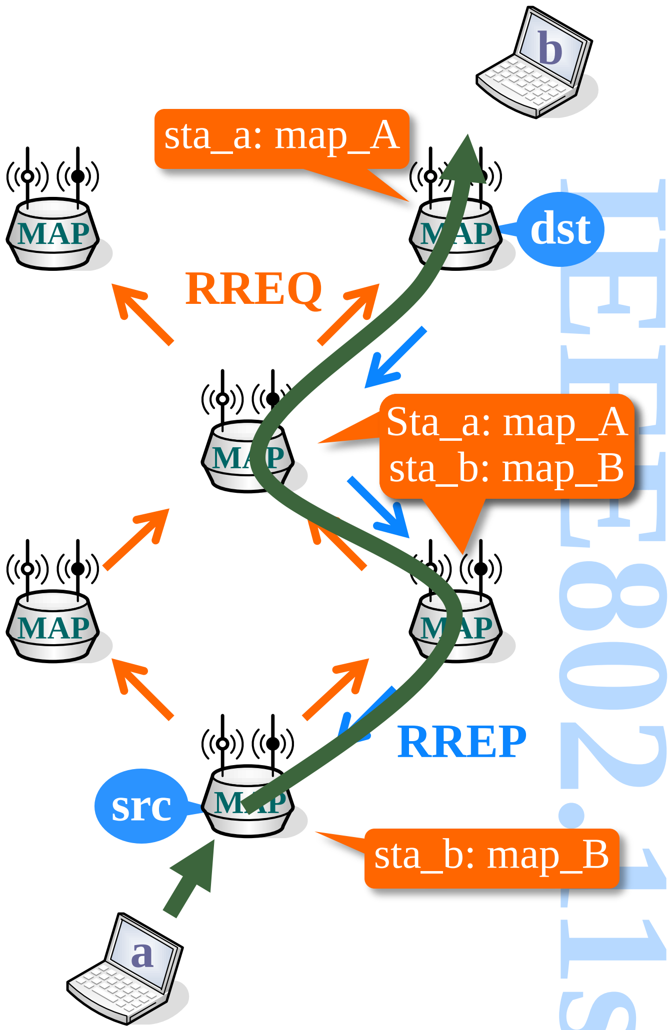
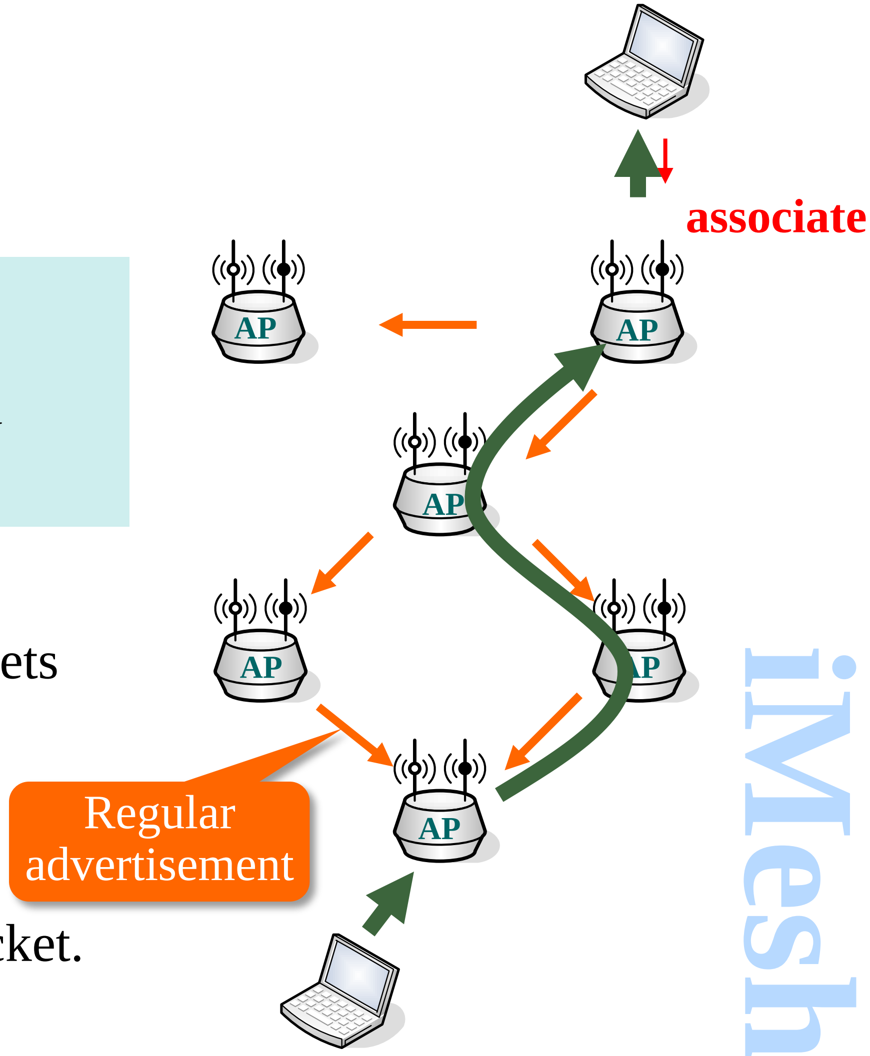


EARLY STUDY - iMesh -

- **Mesh Protocol**
  - Modified OLSR
- **Mapping &Routing**
  - Each AP advertise station’s information periodically.
  - Each AP learns the route to every stations.
- **Handover**
  - When a station changes AP, packets are buffered in the old AP.
  - The new AP advertises station‘s information.
  - The old AP relays the queued packet.
  - APs updates route information.



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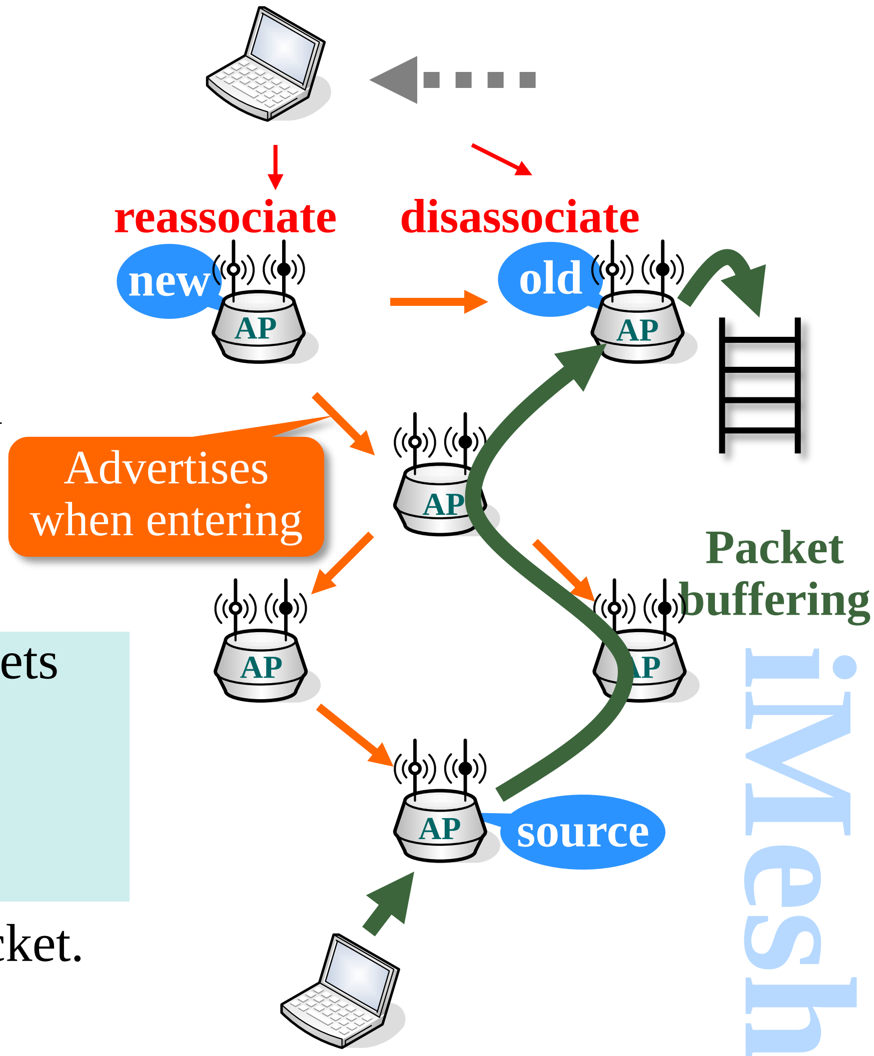
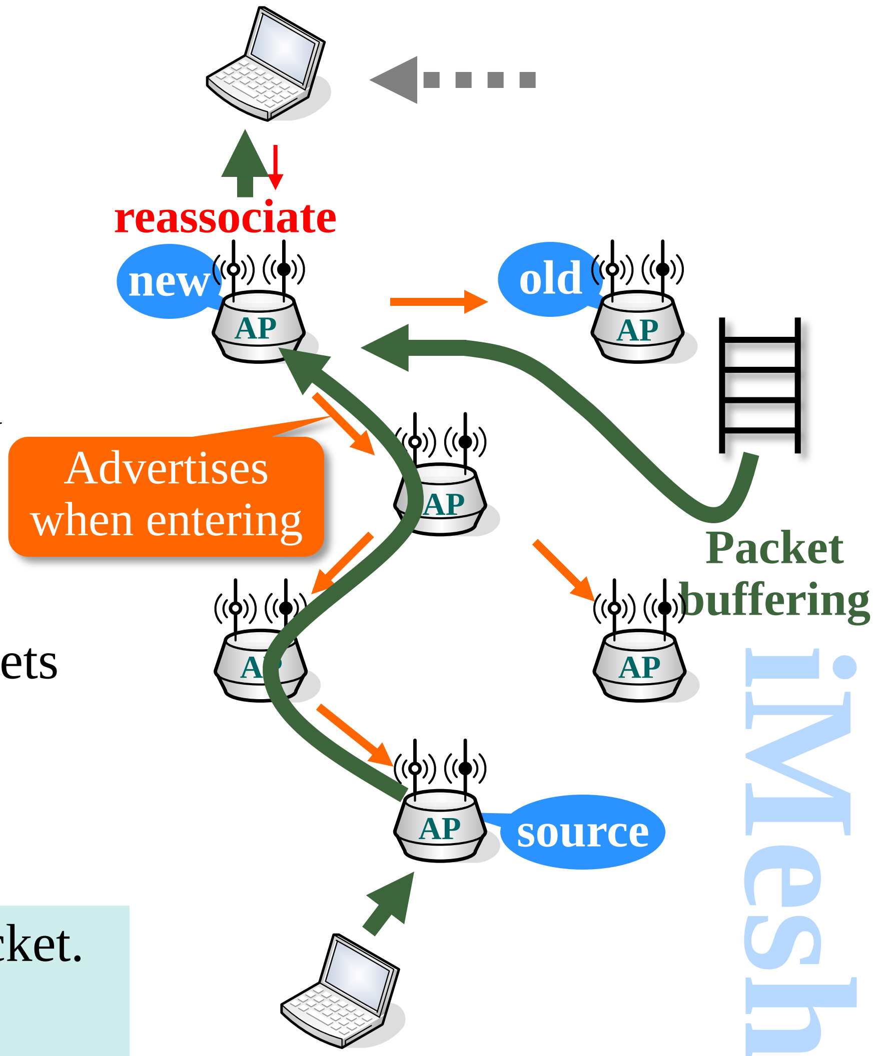
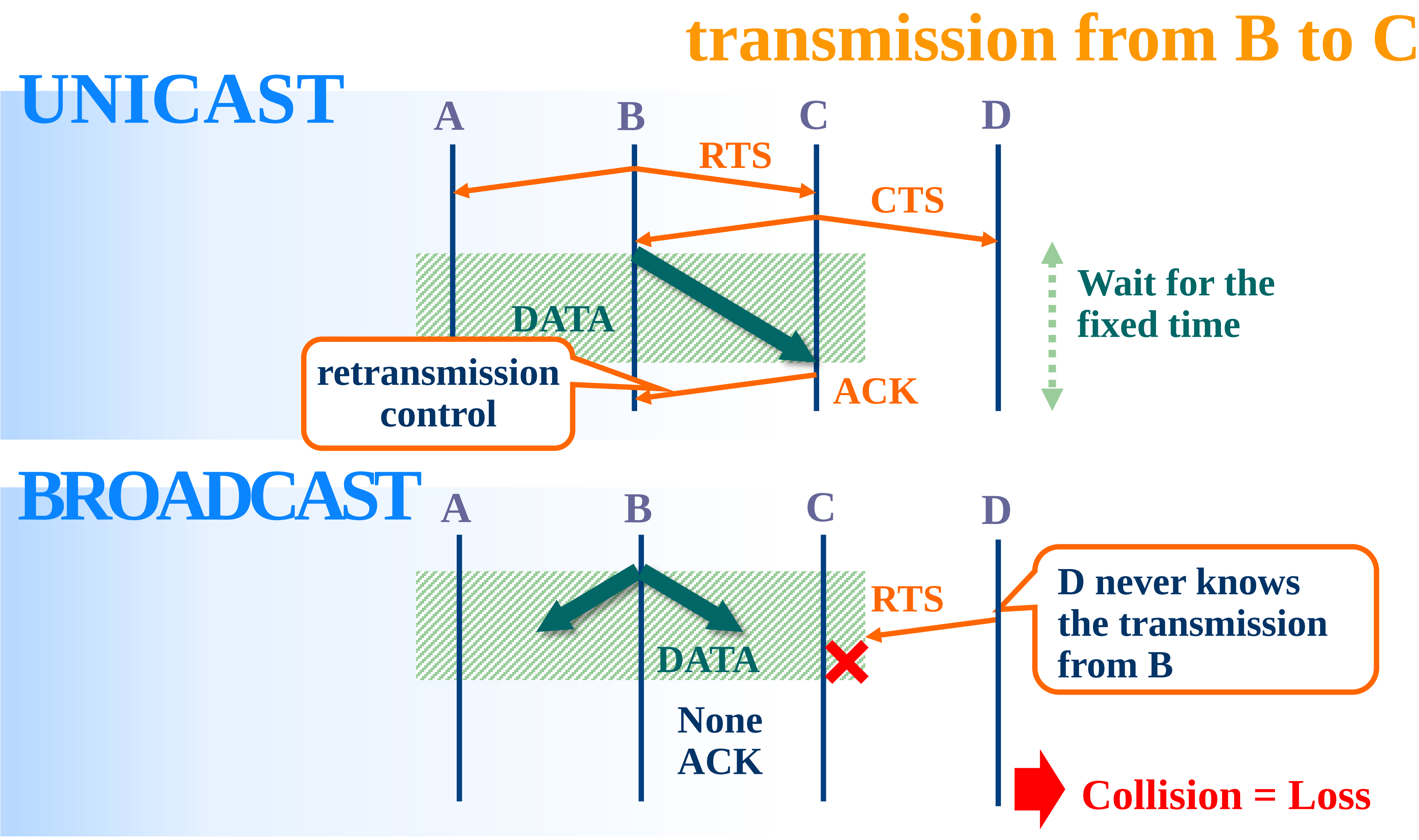


EARLY STUDY - iMesh -

- **Mesh Protocol**
  - Modified OLSR
- **Mapping &Routing**
  - Each AP advertise station's information periodically.
  - Each AP learns the route to every stations.
- **Handover**
  - When a station changes AP, packets are buffered in the old AP.
  - The new AP advertises station's information.
  - The old AP relays the queued packet.
  - APs updates route information.



Disappearances of flooding



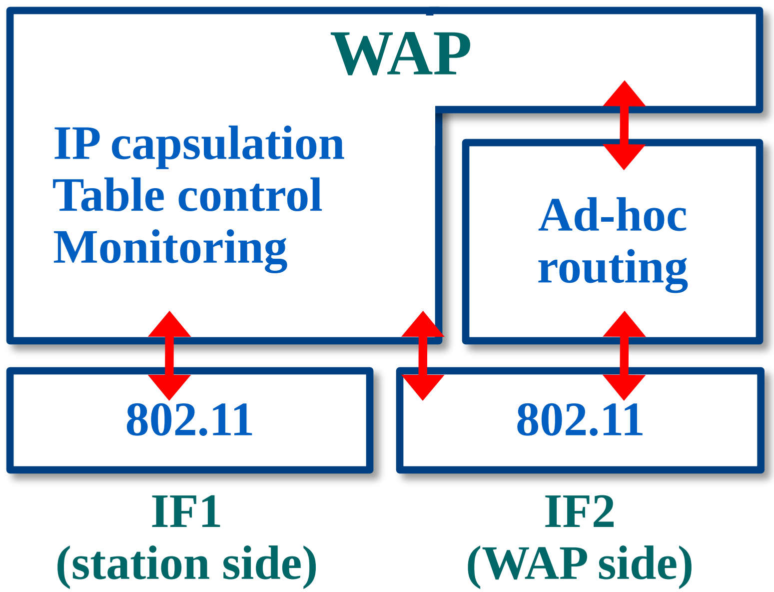
PROPOSAL OF WAPL

WAPL

Wireless Access Point Link

- **Ad-hoc routing protocols can be selected freely.**
- **Control traffic is minimized with the on-demand route establishment.**
- **Seamless handover can be surely achieved.**

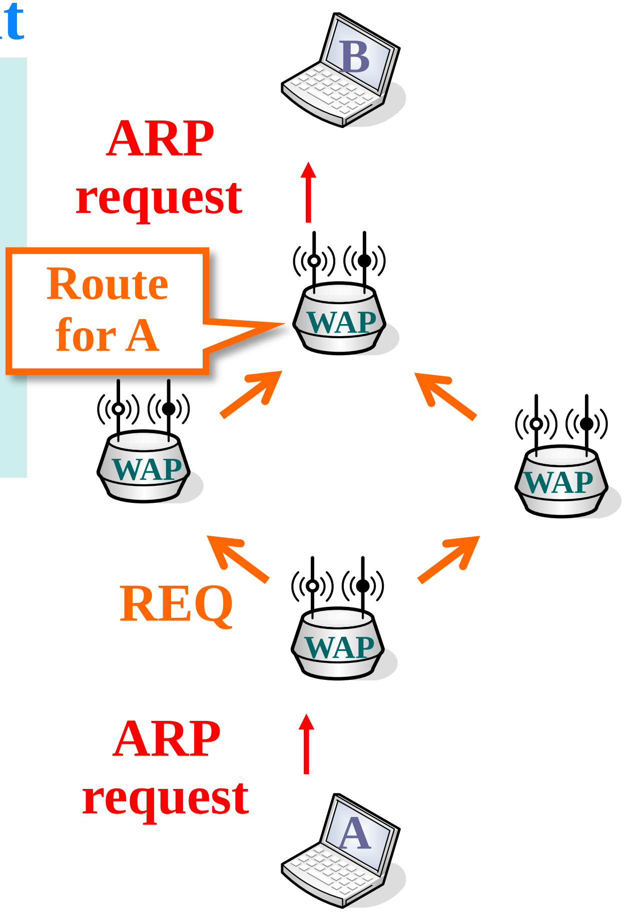
PRINCIPLE OF WAPL - Architecture -



- **Independent from ad-hoc routing protocol.**
  - Any MANET protocol can be selected freely.
  - Routes for stations are established on-demand.

PRINCIPLE OF WAPL - Basic principle -

- **On-demand route establishment**
  - When a source WAP receives ARP request from A, the WAP advertises REQ to the WAP side.
  - WAPs which receive REQ learns the route to A, and transmits an ARP request to the station side.
  - A WAP which receive an ARP reply responds to the source WAP by a unicast.
  - The source WAP studies the route to B, and transmits the ARP reply to A.



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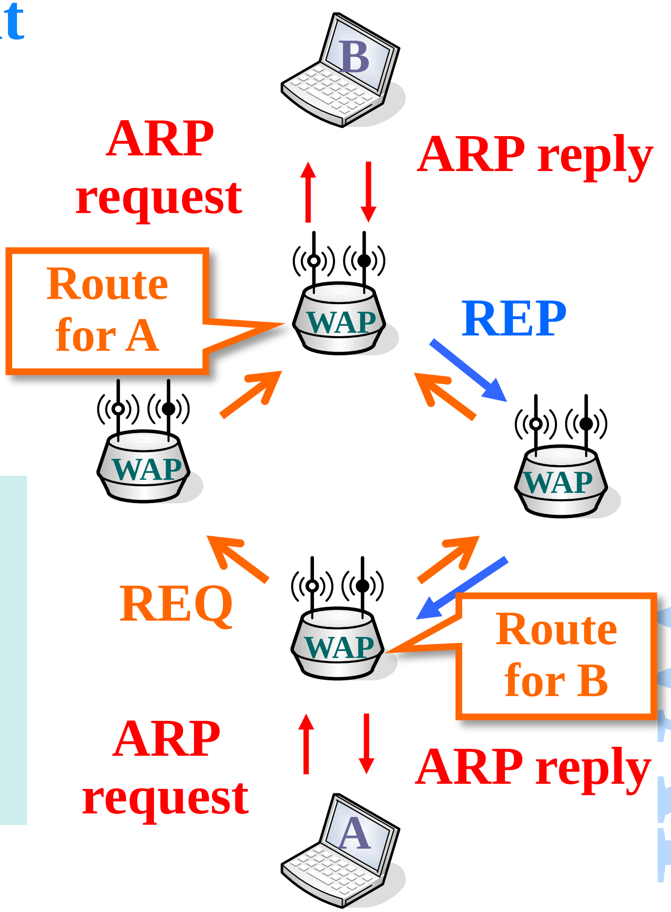

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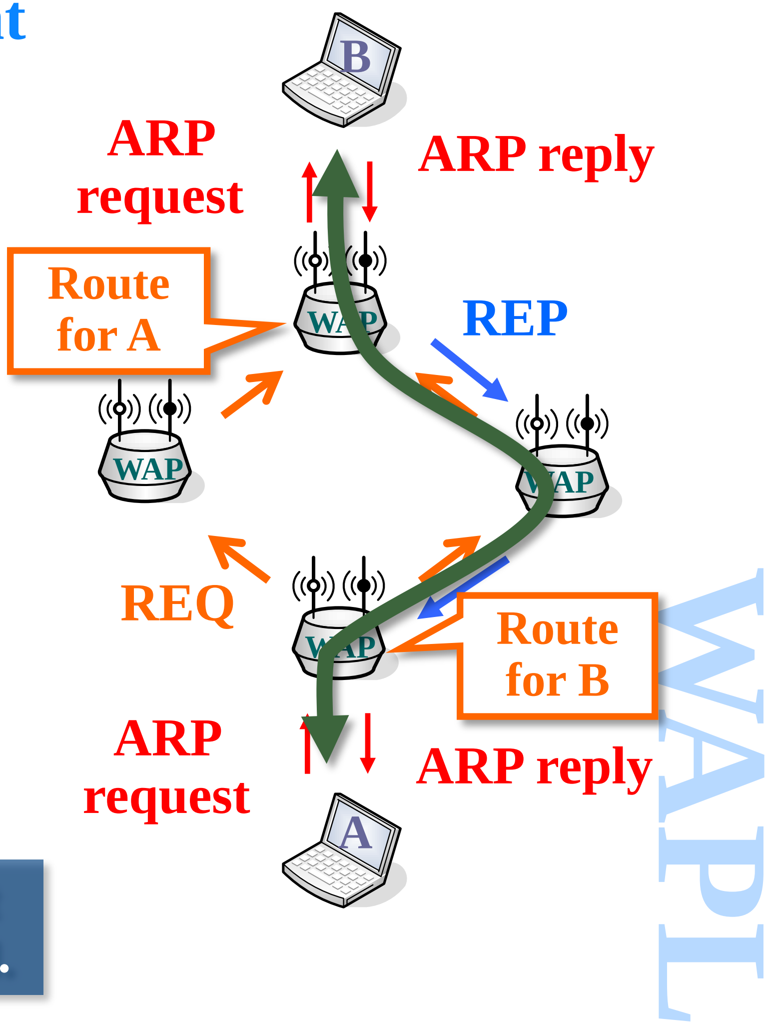
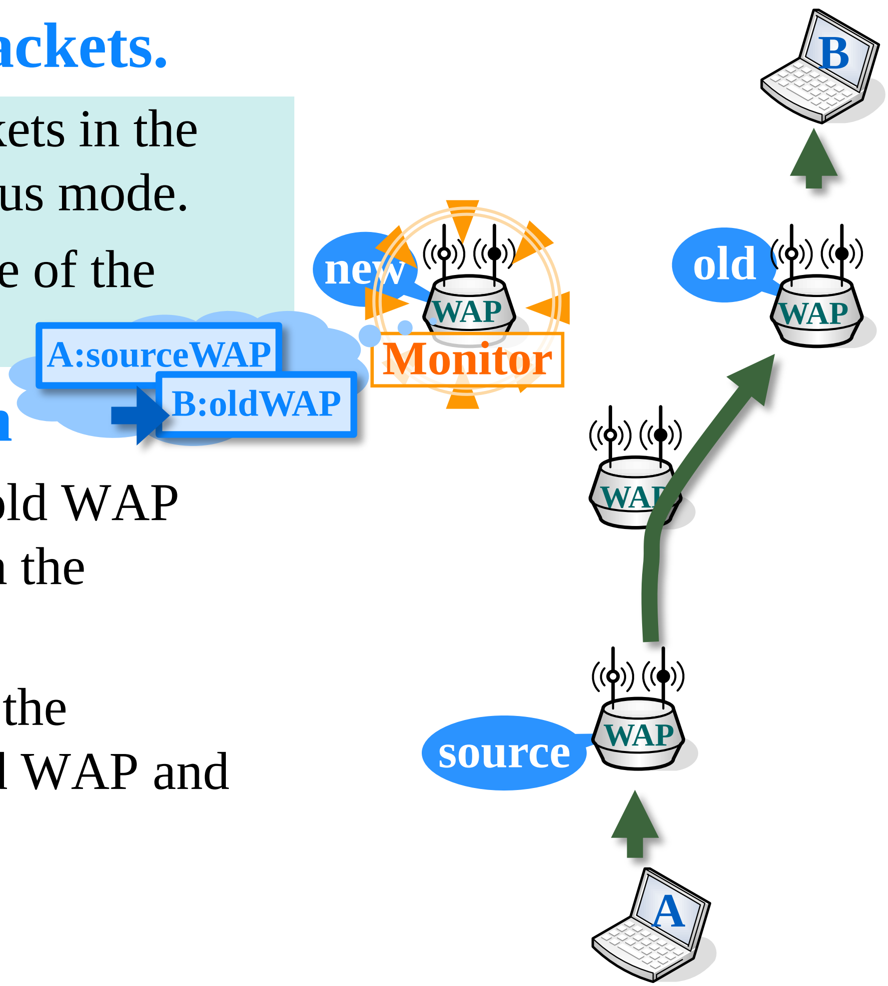


Traffic of control messages is light because of the on-demand method.

PRINCIPLE OF WAPL - handover -

- **Monitoring nearby packets.**
  - Each WAP monitors packets in the vicinity with a promiscuous mode.
  - Each WAP records a route of the communication.
- **Handover notification**
  - The new WAP finds the old WAP and the source WAP from the recorded information.
  - The New WAP transmits the handover notice to the old WAP and the source WAP.



WAPL

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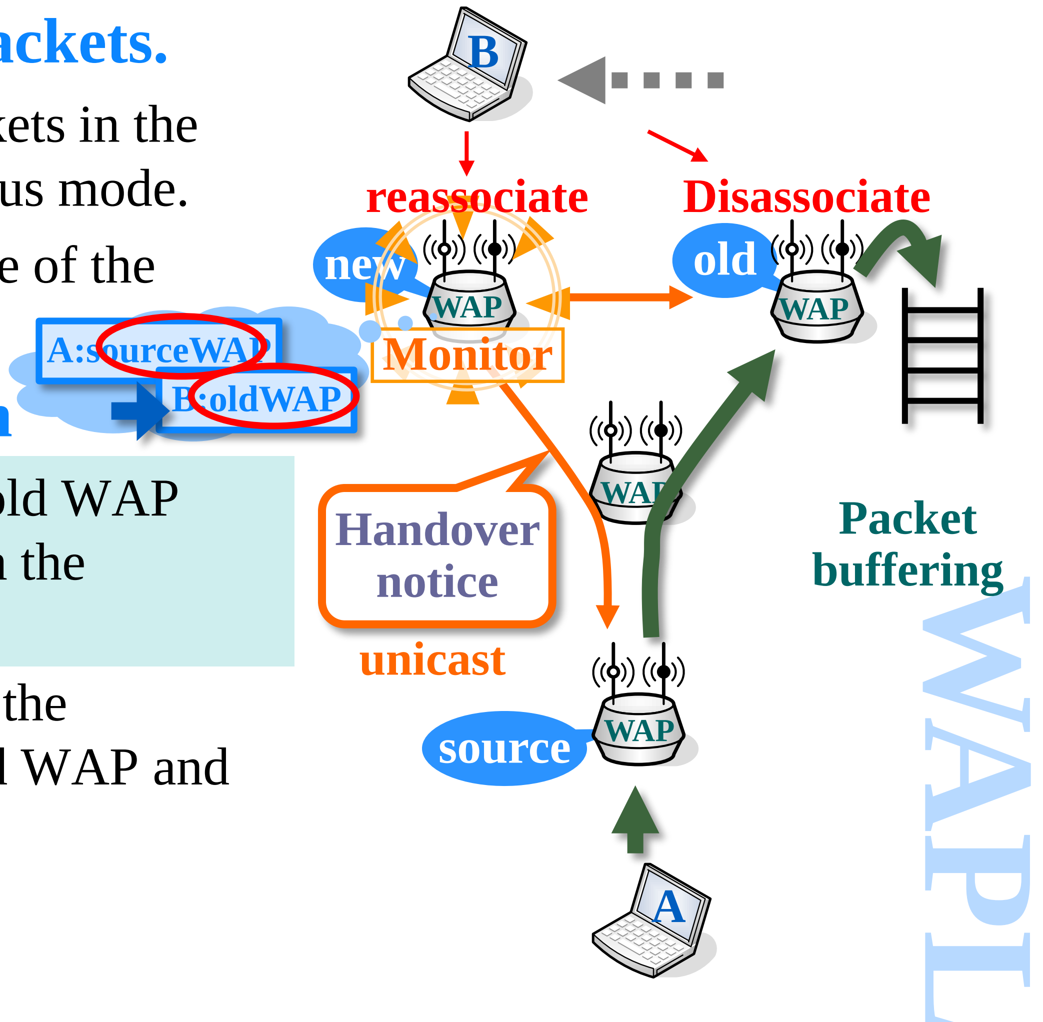

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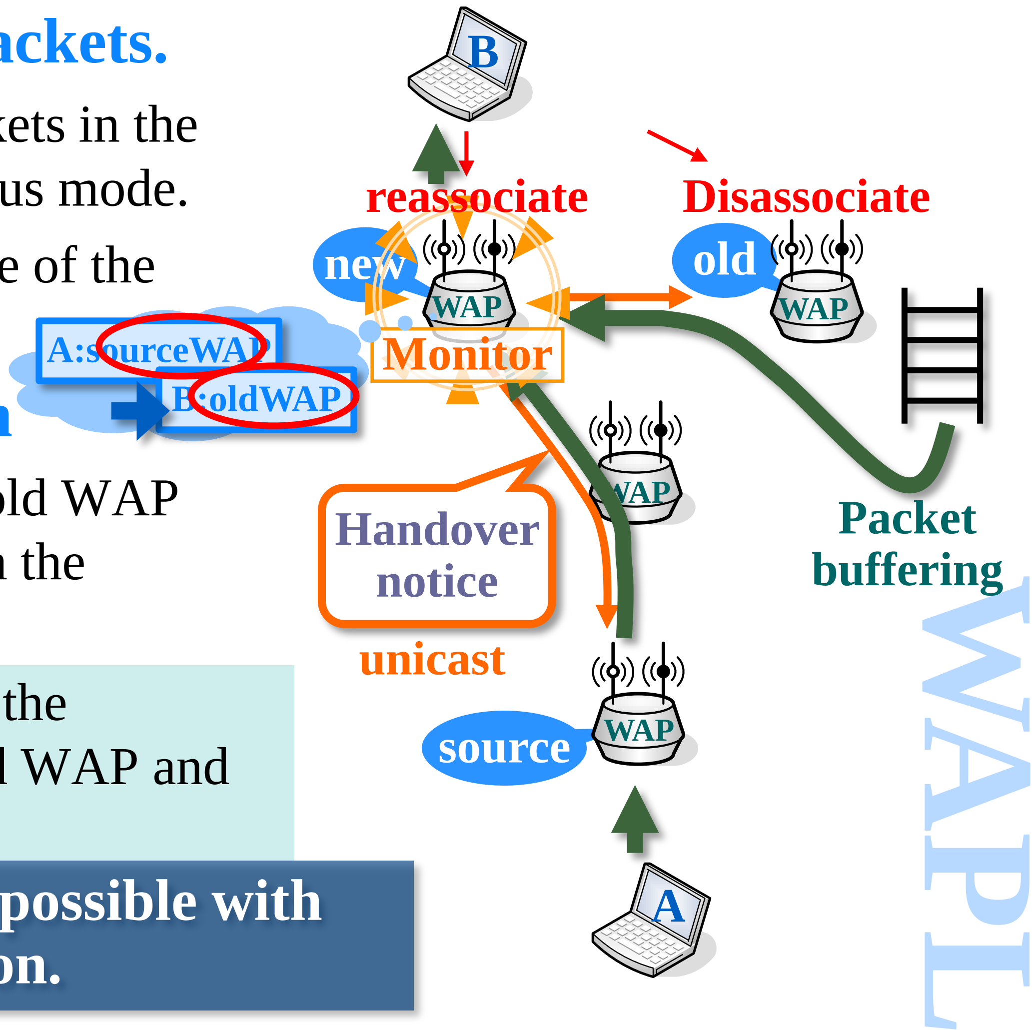
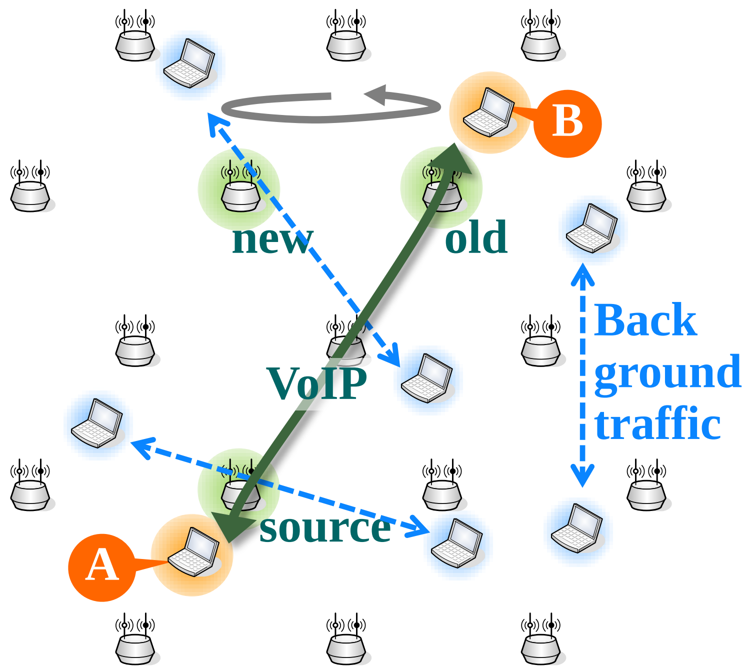
Reliable handover is possible with the unicast notification.



SIMULATION 1

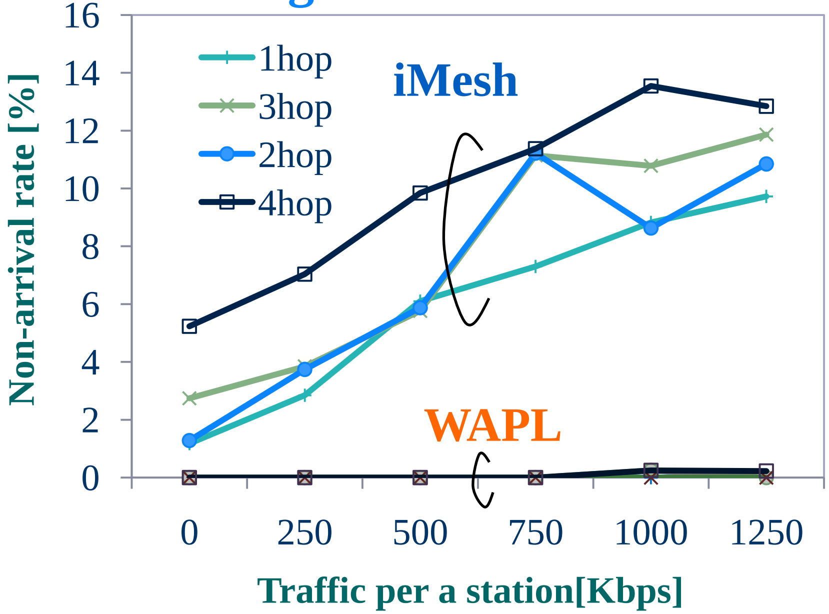
- **Comparison of the non-arrival rates of the handover notification of WAPL and iMesh.**
  - B moves right and left during the communication, and repeats handover.
  - Back ground traffic is provided by other stations.



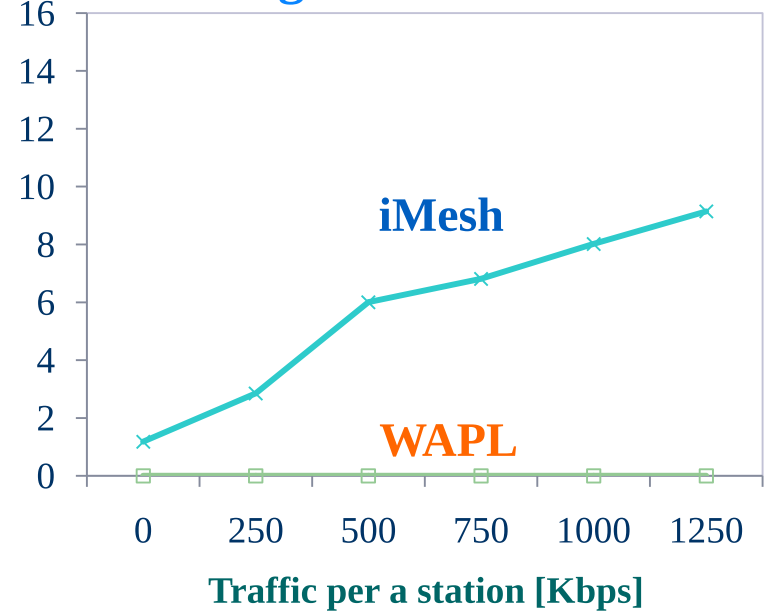
Other conditions	
The number of APs(WAPs)	24
Communication type	VoIP
The number of other station	10
Other station's locations	Random
Mesh protocol	WAPL, iMesh

SIMULATION 1 - result -

Non-arrival rates of handover message at the source AP.



Non-arrival rates of handover message at the old AP

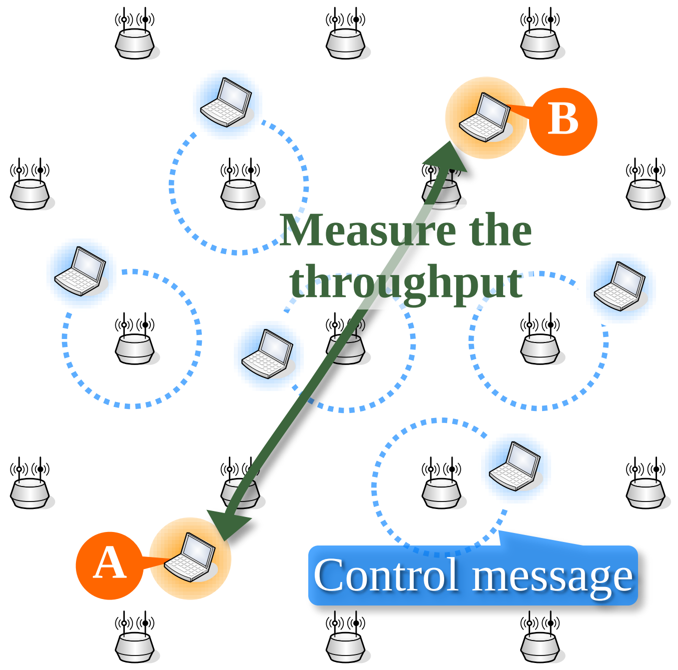


- **To the source AP --- 14% in iMesh, 0% in WAPL**
- **To the old AP --- 10% in iMesh, 0% in WAPL**

The effect of unicast notification is significant.

SIMULATION 2

- **Influence of the control messages of WAPL**
  - A and B communicates with FTP, and the throughput is measured.
  - Other stations repeat the initiation of communication.



Other conditions	
The number of WAP	52
FTP period	100 sec
The number of stations per a WAP	4
Initiation intervals per a station	60 sec
Protocol	WAPL(OLSR)

***To measure only the influence of the control message, data packets in a WAP side are removed.**

SIMULATION 2 - result -

Degradation rates of throughput.

Distance	Throughput		Degradation rates
	Each station does not start communication	Each station start communication in every 60 sec.	
1hop	7.65 Mbps	7.61Mbps	0.54%
2hop	7.48	7.40	1.11
3hop	5.05	5.00	0.97
4hop	3.65	3.62	0.82

- **The degradation rates are about 1% or less in every hop counts.**

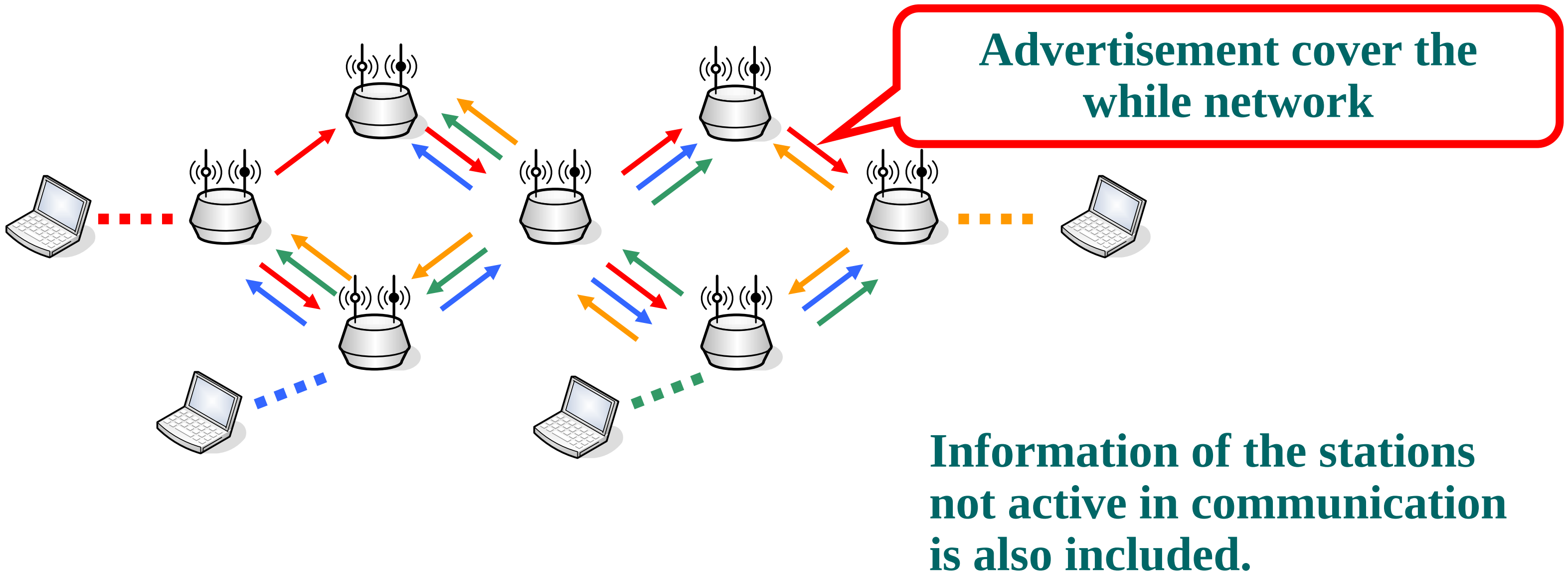
The on-demand method applied by WAPL does not give any significant influence on general communication.

SUMMARY AND FUTURE PLANS

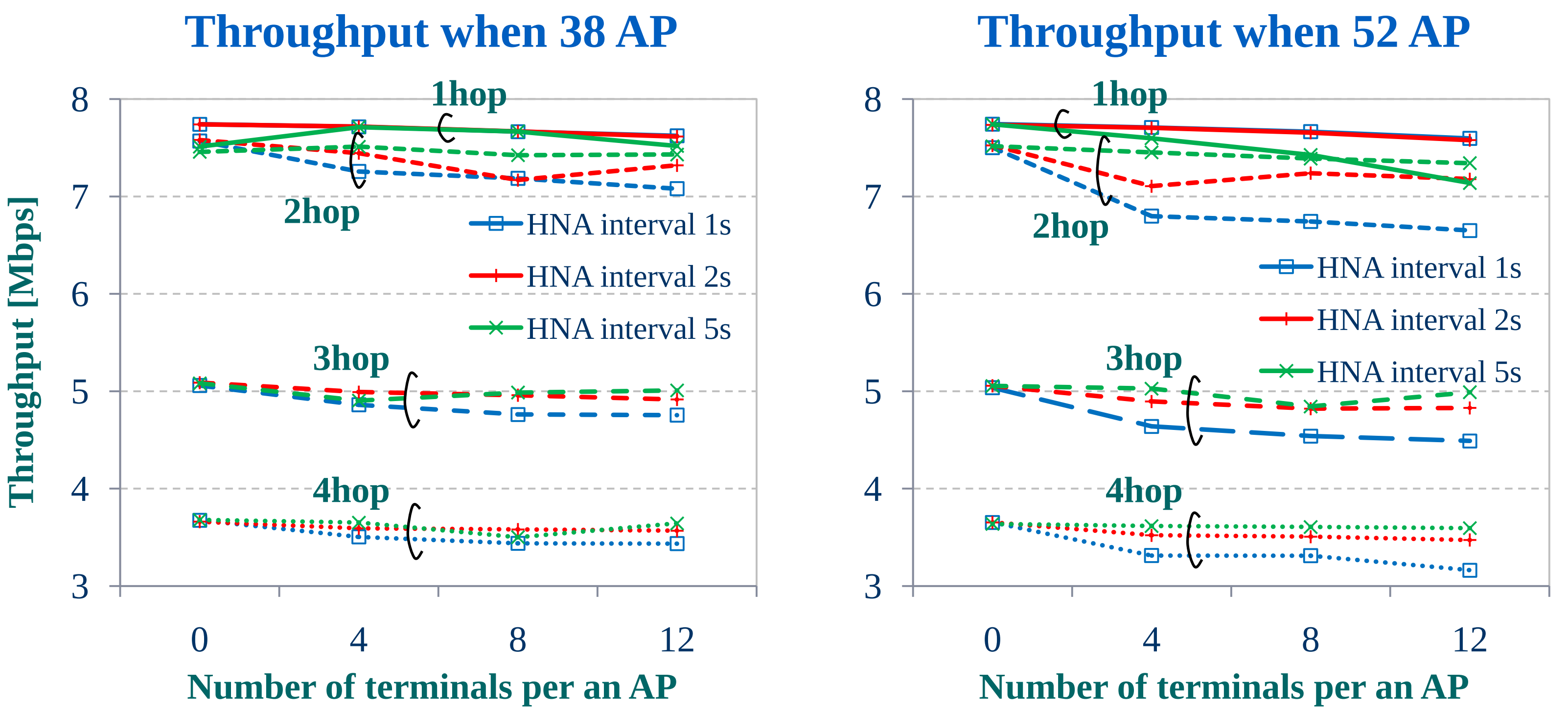
- **Proposal for WAPL**
  - Ad-hoc routing protocols can be selected freely.
  - Control traffic is minimized with the route establishment.
  - Seamless handover can be surely achieved.
- **Simulation result**
  - Non-arrival rates of handover messages are almost 0 in WAPL.
  - On-demand route establishment in WAPL does not give any influence on general communication.
- **Future plan**
  - Implementation of WAPL and its evaluation.

A load of advertisement of iMesh

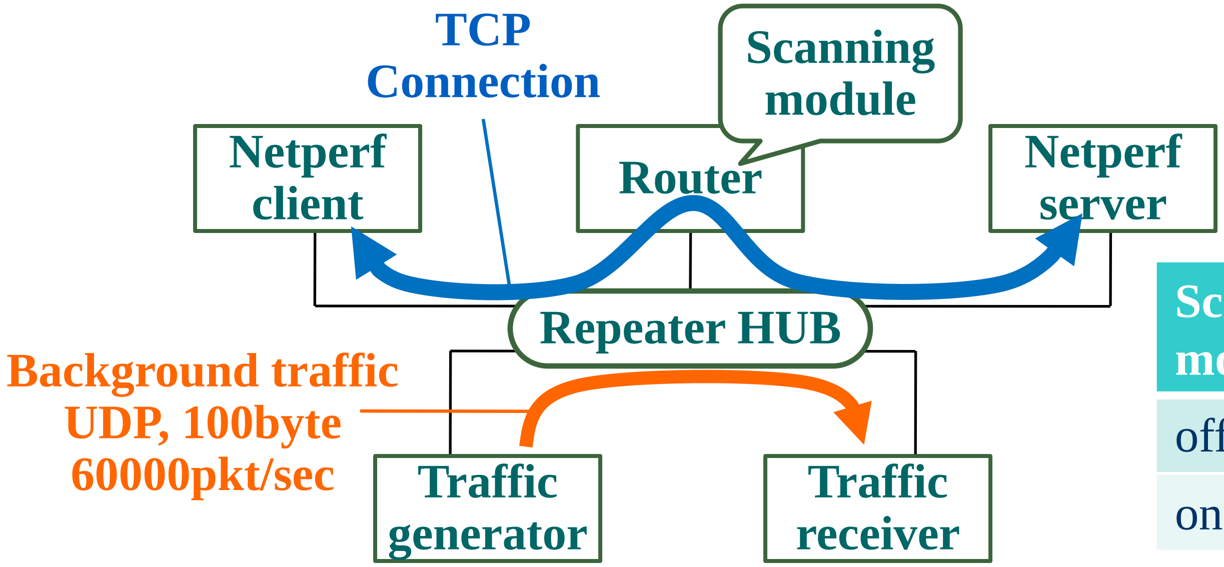
- **In iMesh, the size of network and the number of connection stations give influence with network**
  - iMesh care non-arrival of handover message by regularly advertisement.



The influence of advertisement of iMesh



A load of monitoring



Scanning module	Throughput
off	6.34 Mbps
on	6.30 Mbps

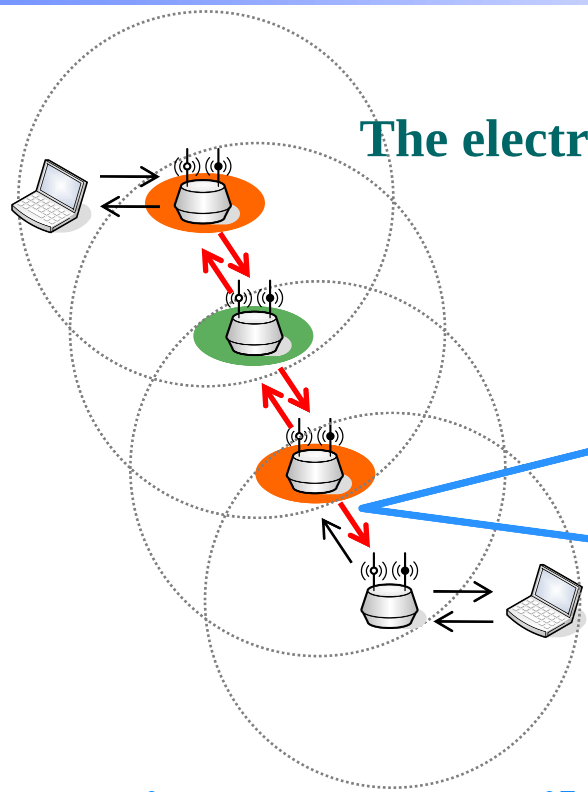
- **Scanning module that has monitoring and table management function is realized in router.**
- **Traffic generator give network sufficient load.**
- **Compare scanning modules being on and off.**

⇨ the rate of degradation is about 0.6%.

Scanning has no influence with router performance.

Influence of VoIP packet with handover notice

The electric wave that (orange) transmits influence (green)



VoIP
172Kbyte
50 times per second
Two way communication

= 128Kbps

- There is every possibility that VoIP and handover notice overlap

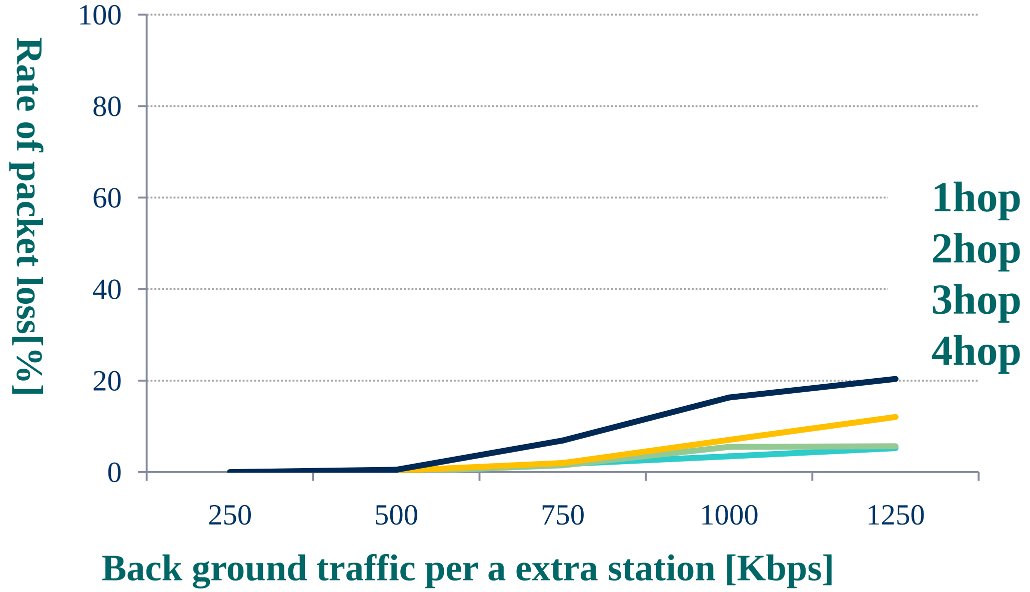
Studies for multi-channel at MANET

- C. Jenhui and C. Yen-Da, "AMNP: Ad Hoc Multichannel Negotiation Protocol for Multihop Mobile Wireless Networks", ICC2004
- N. Jain, etc., "A Multichannel CSMA MAC Protocol with Receiver-Based Channel Selection for Multihop Wireless Networks", IC3N2001
- Shih-Lin Wu, etc., "A New Multi-Channel MAC Protocol with On-Demand Channel Assignment for Multi-Hop Mobile Ad Hoc Networks", ISPAN2000
- H. Wing-Chung, etc., "A Dynamic Multi-Channel MAC for Ad Hoc LAN", in 21st Biennial Symposium on Communications
- A. Atul, etc., "A Multi-Radio Unification Protocol for IEEE 802.11 Wireless Networks" in *IEEE International Conference on Broadband Networks*
- *Etc…*

Seamless handover of IEEE802.11s

- **The method of using other standard of 802**
  - 802.21 (802.11F, 802.11r)
    - When the station switch to new AP, a broadcast is conducted to update route of each AP (layer two update).
    - In Mesh network, broadcast is changed into flooding.
    - The problem that iMesh also has is occurred.

The rate of the packet loss in simulation 1



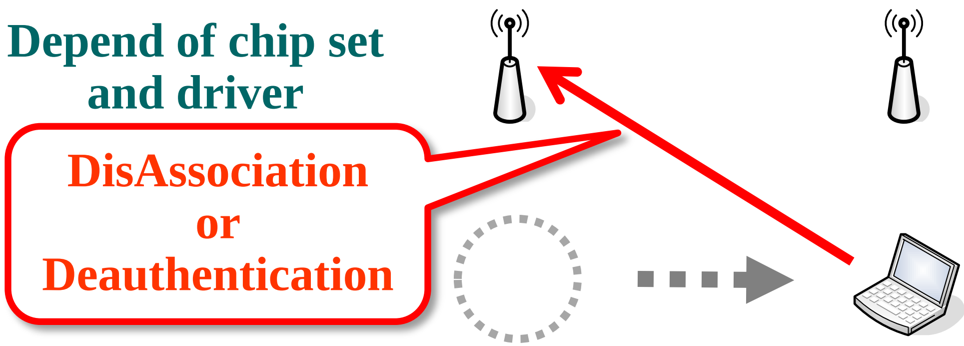
- Measure the rate of the packet loss in same background traffic

- The rate become too heavy since 1000Kbps

Alteration to ns-2

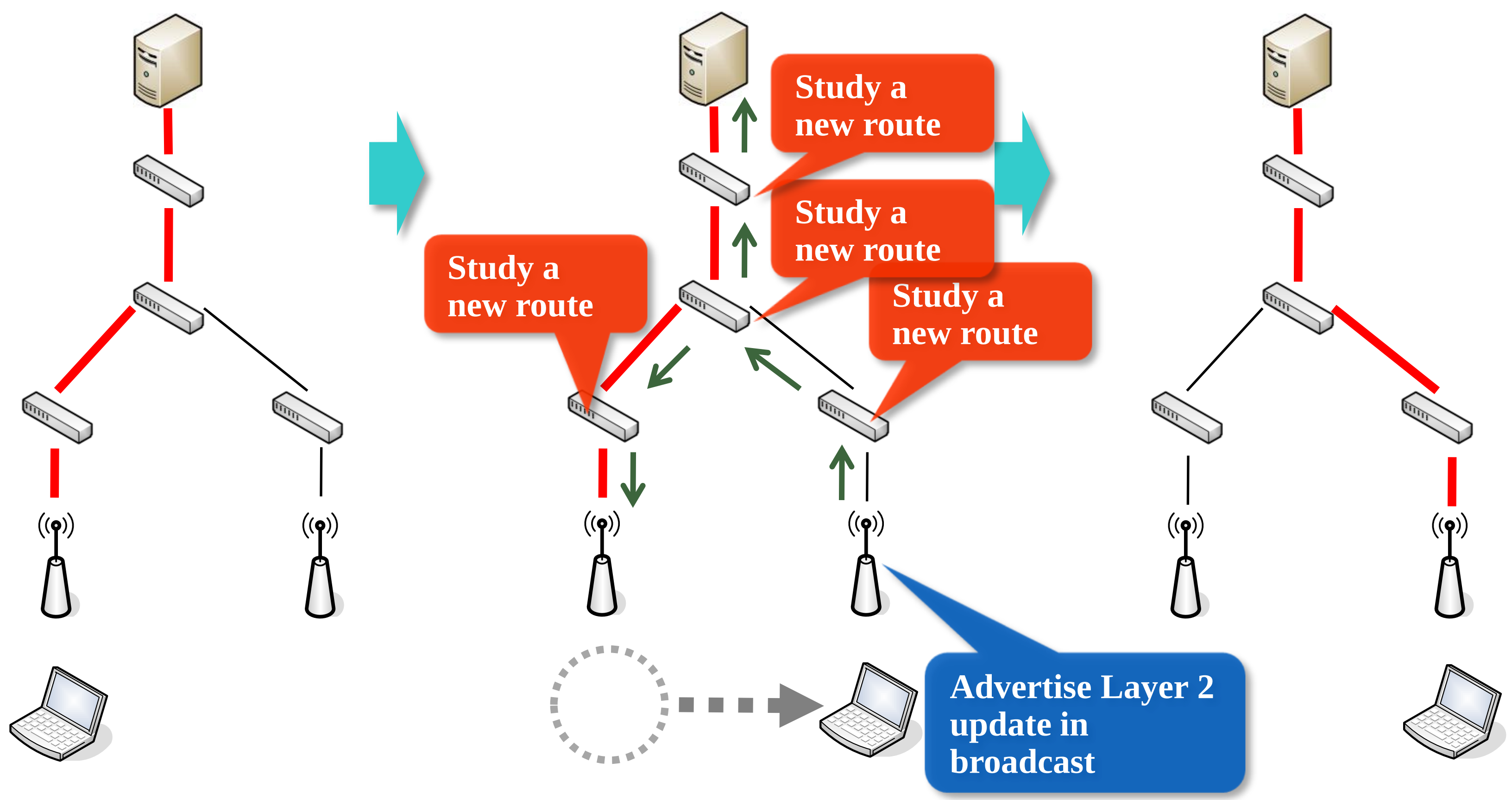
- Judging the AP departures and reassociation by strength of radio waves.
- Processing disassociation as well as reassociations.
- WAP need two interface (infrastructure and ad-hoc) is realized by directly linking the internal modules of the two interface.
- WAPL and iMesh method.

Processing for disassociation

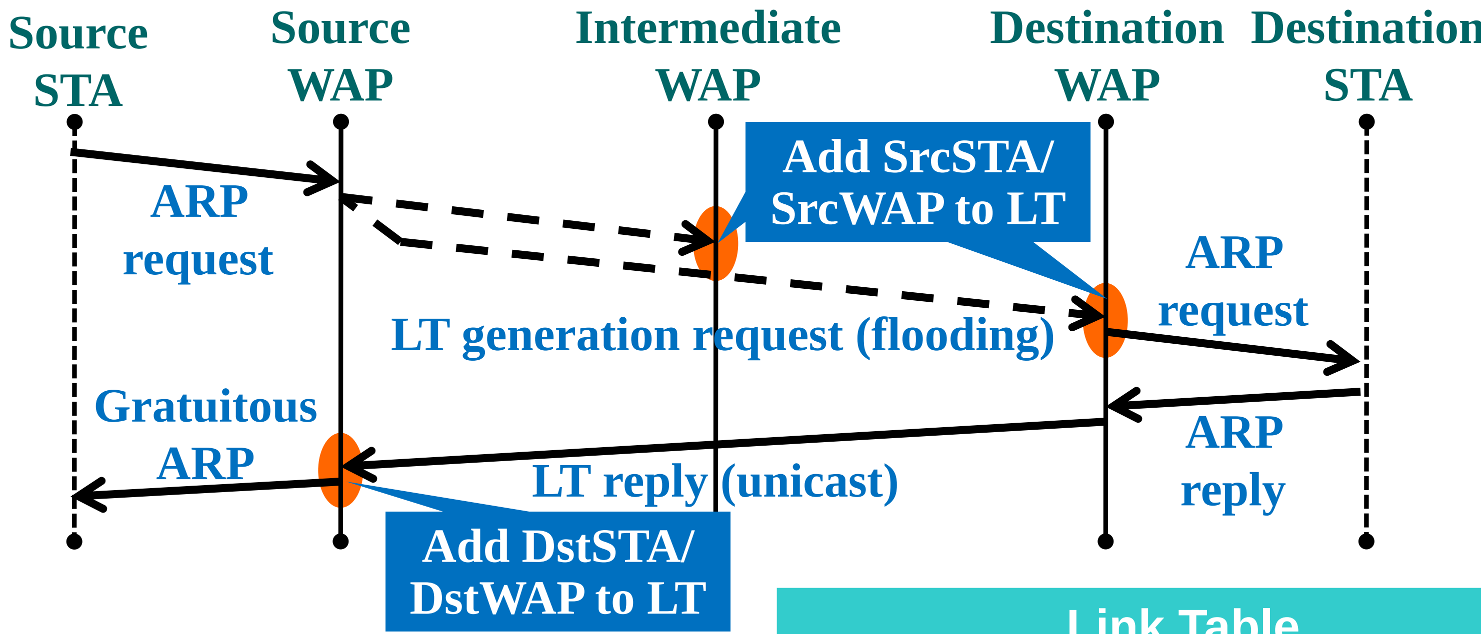


	Different ESSID	Same ESSID
WinXP(AtherosWNA)	Deauthentication	-
WinXP(Intel2945,3945)	Nothing	Nothing
Linux(ipw2945)	Disassociation	Disassociation
Linux(ipw3945)	Nothing	Nothing
Linux(MADWIFI)	Disassociation	Disassociation
Linux(orinoco_cs)	Nothing	Nothing
ICOM wireless cell phone	Deauthentication	Deauthentication

Layer 2 update



Link Table



Link Table	
WAP IP address	STA IP address

- Intermediate and Dst WAP generate LT that map Src WAP with Src Station when they receive LT generation request.
- Source WAP generate LT that map Dst WAP with Dst statin when that receive LT reply.