A CLNP-based Protocol for Mobile End Systems within an Area

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Abstract

In this paper, we propose a protocol for supporting mobile End Systems (ESs) that move within an area in ConnectionLess-mode Network Protocol (CLNP) environment. Traffic caused by control Protocol Data Units (PDUs) under frequent ES migration can be reduced by separating the roles of Intermediate Systems (ISs); 1) generating and propagating the information of the default location of an ES, 2) communicating directly to the ES and notifying the IS performing the role 1) of the current location of the ES. In addition, ISs may use a new caching mechanism for efficiency. This protocol has the following advantages: First, there is no need for mobile ESs to be changed. Second, ISs implementing this protocol can coexist with the conventional ISs. Third, it does not require any change to the areas which do not have mobile ESs, hence it is easy to apply it to the existing networks.

1 Introduction

New architecture for mobile communication has been expected, providing users with a means to access the computer resources from anywhere they currently locate. One of the most serious problems to support mobile communication in existing networks is *identification of systems.* In such protocols as OSI or TCP/IP, since the network address of an End System (ES) is used not only as an identifier but also as a location indicator, it should be changed when the ES moves to another network. Hence, an alternate method for system identification will be needed, which can assign each of ESs an identifier independent of location. Moreover, a dynamic mapping mechanism from an identifier to its current network address should be considered.

Another problem is *heavy traffic caused by control Protocol Data Units (PDUs).* In order to resolve the problem of the identification of systems, various control PDUs will be used. If these PDUs are broadcasted, the network will be in danger of congestion under frequent ES migration.

In addition, *quickness of migration procedures* is also a matter to be solved. If it takes long time to update the routing table with new location information when an ES moves, a connection of the upper layer may be disconnected because of routing loop or loss of Network PDUs (NPDUs).

We may assume that, in many practical cases, migration of mobile ESs is limited to some range, such as the floor of an office or a university campus. Since the network address of an ES does not change in such migration in ConnectionLess-mode Network Protocol (CLNP) [3] environment, that is, the first problem mentioned above does not occur, we can support mobile ESs with the Intermediate System to Intermediate System protocol (IS-IS) [5] , which is one of a link state protocol. However, it is not enough to solve the last two problems if many ESs move frequently.

Several protocols for mobile communication have been proposed based on IP [2], [6], [8] and based on CLNP [1], [7]. These approaches, however, mainly focused on the problem of the identification of systems, and the last two problems are rather considered to be of secondary importance.

Furthermore, designing a protocol to support ES migration within an area gives rise to other issues. First, the protocol should *not require any change of ESs.* There is a possibility that each area adopts a different protocol depending on its condition, i.e., the number of mobile ESs, migration frequency, network topology and so on. If it is so and the protocol requires some functions of ESs, ESs must change the protocol when they move to another area. This will be a burden on portable ESs. Thus, it should be ISs to support ES migration.

Second, adopting the protocol should *not have effect on the other areas.* To interconnect with other areas as before, the area adopting the protocol must be considered by them as if it operated IS-IS instead of the protocol.

Therefore, in this paper, we propose an efficient

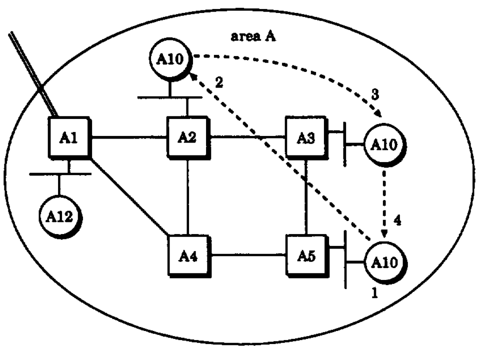

Figure 1: An example of network topology of an area.

protocol for supporting ES migration restricted within an area under OSI environment in which CLNP, IS-IS, and the End System to Intermediate System protocol (ES-IS) [4] operate. We especially put emphasis on the state of Intermediate Systems (ISs).

The rest of the paper is organized as follows: We show several problems of supporting ES migration by IS-IS in section 2. In section 3, we describe our protocol and evaluate it in section 4. In section 5, we briefly compare our protocol with some related works. We summarize the paper and mention about future works in section 6.

2 Supporting mobile ESs with IS-IS

In IS-IS, a routing domain is broken into subdomains called *areas*. Routing within an area is called *level 1 routing* and routing among areas is called *level 2 routing.* The level 1 routing and the level 2 routing are designed to be independent from each other, then we can take only the level 1 routing into consideration to handling ES migration within an area.

An IS which keeps routing information and routes NPDUs within an area is called *level 1 IS.* Each level 1 IS is responsible for generating a set of list including the *system IDentifiers(IDs)* of the neighboring ESs, which is called *Link State PDU(LSP),* and propagating them throughout the area. Thereby all ISs in the area can keep the complete map of the area and calculate the best route to each destination. Not only when timer expires, but also when the state of neighbor systems or circuits change, an IS must generate and propagate a new LSP.

Here we show how IS-IS works when an ES moves within an area. Figure 1 depicts an example of an area. A circle shows an ES and a square shows an IS. A line shows a level 1 circuit and a double line shows a level 2 circuit.

Note that the network address of each system is expressed by the sequence of an area address, an ID and a network selector. In Figure 1, the capital letter 'A' stands for an area address and a numeral following after the area address, like '10', stands for an ID.

1) When ES A10 comes up as a neighbor of IS A5 (1 in Figure 1), A5 generates and propagates a level 1 LSP including the ID of A5 throughout area A. If an IS in the area receives a PDU destined to A10, it forwards the PDU toward A5 according to the LSP.

2) A10 moving to and becoming a neighbor of IS A2 (2), A2 informs the other ISs of migration of A10 by propagating an LSP. On the other hand, detecting that A10 has gone, A5 re-generates the changed LSP which does not include the ID of A10 so as to inform the other ISs that A10 is no longer a neighbor of A5.

3) Similarly, on each successive migration of A10 (3, 4), two neighboring ISs, that is the previously neighboring IS and the newly neighboring IS, generate LSPs and propagate them all over the area to claim the deletion or creation of relationship to A10, respectively.

In this way, IS-IS can deal with ES migration within an area, however, network congestion will be caused by flooded LSPs if many ESs move at a time.

Actually the minimum interval of generating and transmitting LSPs is controlled by *minimumLSPGenerationInterval, minimumLSPTransmissionInterval* and *minimumBroadcastLSPTransmissionInterval* parameters and their default values are 30 seconds, 5 seconds, and 1 second, respectively. Though, if these parameters are set to bigger values to suppress the generation of LSPs, ISs cannot update their forwarding database immediately after ES migration, which may cause the disconnection of a connection of the upper layer in a large-scaled network or under frequent ES migration. Therefore IS-IS is practically insufficient to support ES migration.

3 Default Forwarding Protocol (DFP)

3.1 Concept

In terms of the relationship with an ES, an IS is in either of the two states; *Normal State* and *Neighbor State* in IS-IS. An IS in the Normal State (termed *Neighbor IS (NIS)*) is adjacent to the ES while an IS in the Normal State (termed *normal IS*) is not adjacent to the ES. Here, "adjacent" means that they can communicate each other directly. The NIS of an ES has two major roles; 1) detecting the existence of the ES and handling NPDUs to/from it, 2) generating and propagating an LSP so that the other ISs know the location of the ES. An IS should also generate an LSP when it detects that the ES has been no longer a neighbor. After that it changes the state. Hence double LSPs are generated on every ES migration.

We divide the Neighbor State into three states; *Default Neighbor State*, *Current Neighbor State* and *Default and Current Neighbor State* in order to restrain the state transition between the Neighbor State and the Normal State, which causes the generation of LSPs.

An IS in the Default Neighbor State (termed *default NIS*) is responsible for only 2) of the above roles and an IS in the Current Neighbor State (termed *current NIS*) is responsible for only 1) of the above roles respectively. The default NIS will not change even though the ES moves to another IS and continue to generate and propagate LSPs periodically. The current NIS will change on every ES migration and notify the default NIS that the ES is now located adjacent to it. The default and current NIS is the same as the neighbor IS in IS-IS, the other ISs consider it as the default NIS.

If an normal IS receives an NPDU addressed to the ES, it forwards the NPDU toward the default NIS according to the knowledge obtained from the LSP. Hence we call this protocol *Default Forwarding Protocol (DFP)*.

ISs exchange the *ES information* for each ES, which is represented by the pair of the ID of the ES and the ID of the current NIS. Each IS keeps it in its *ES information base* so as to refer to it when it forwards NPDUs.

3.2 Exchanged PDU types

DFP uses the following PDUs. The first four PDUs are substantially ISO 8473 NPDUs enhanced by new option fields. The last one is the level 1 LSP with a new option.

MIG_NTF: The current NIS uses an *MIG_NTF* to notify the default NIS of ES's migration. The option part includes the IDs of the ES and of current NIS.

MIG_ACK: The default NIS which has received an *MIG_NTF* uses an *MIG_ACK* to send an acknowledgment to the current NIS.

FWD_NPDU: An IS uses an *FWD_NPDU* to forward an NPDU to another IS. The option part includes the original destination address and source address of the NPDU.

INF_NPDU: The current NIS uses an *INF_NPDU* to inform other ISs in the same area of neighbor ES information. The current IS may add the ID of it and the neighbor ES to the option field of an arbitrary NPDU sent by neighboring ESs. It is desirable that ISs which can make an *INF_NPDU* can disable this function whenever it is required. When an IS receive an *INF_NPDU*, it should check whether it is sent from an IS in the same area.

SPT_DFP: An IS notifies the other ISs in the same area of supporting DFP by sending an *SPT_DFP*.

3.3 Examples

We show some scenarios of the operation of DFP using Figure 1.

ES comes up: When IS A5 notices new neighbor ES A10 (1 in Figure 1), it generates and floods an LSP including the ID of A10. A5 becomes the default NIS of A10.

Migration notification and PDU forwarding:

1) After A10 moves to IS A2 (2), A2 becomes the current NIS of A10 and sends an *MIG_NTF* to A5 to inform that it is the current NIS of the A10.
2) Receiving the *MIG_NTF*, A5 reply to it by sending an *MIG_ACK*. A5 then store the ES information contained in the *MIG_NTF* in its ES information base.
3) If IS A1 receives a PDU destined to A10 from ES A12, it forwards the PDU toward A5, the default NIS of A10.
4) On receipt of the PDU, A5 changes it to an *FWD_NPDU*, setting the destination address field to A2, the current NIS of A10, and sends it to A2.
5) Receiving the *FWD_NPDU* whose original destination address is A10, A2 remakes the original PDU and hands it to A10.

Caching mechanism: A transit IS, A4, may cache the ES information included in the *MIG_NTF* to improve communication efficiency.

1) A4 caches the ES information contained in the *MIG_NTF* sent from A2 to A5.
2) When A4 receives a PDU destined to A10, it changes the PDU into an *FWD_NPDU* according to the ES information it keeps, and sends it to A2.

Obsolete cache elimination: Assume that the ES subsequently moves to be adjacent to IS A3 (3).

1) A3 sends an *MIG_NTF* to A5.
2) If A1 receives a PDU addressed to A10 from A12, it forwards the PDU toward A5.
3) On the way to A5, the PDU is changed into an *FWD_NPDU* by A4 according to the ES information and forwarded to A2.
4) Since A2 has not already been the current NIS of A10, it rewrites the destination address field of the *FWD_NPDU* to the default NIS of A10 and forwards it toward A5.
5) Receiving that *FWD_NPDU* from A2, A4 notices that its ES information of A10 has already been obsolete and clears it from its ES information base. Then A4 forwards the PDU to A5.
6) A5 forwards the PDU to A3, the current NIS of A10.

In this way, PDUs are correctly routed by appropriate decision rules to decide the order of the ES information described in the next clause, even if there are some obsolete cached information.

ES information dissemination: The current NIS may add the ES information to an arbitrary NPDU in order to disseminate the ES information throughout the area.

1) A10 passes a PDU, directed to A12, to A3.
2) A3 changes it into an *INF_NPDU* adding the ES information and forwards it to A1.
3) A1 caches the ES information into its ES information base and reconstructs the original NPDU from the *INF_NPDU* in order to hand it to A12.
4) At this time, the transit IS A2 may cache the ES information.

Thus, an IS can disseminate the ES information and then improve communication efficiency.

Cooperation with conventional ISs: ISs implementing DFP and ISs not implementing DFP can cooperate with each other. In other words, not all ISs are required to implement DFP. ISs implementing DFP must represent that they support DFP to each other by sending *SPT_DFP*s. The only enhancement to the conventional ISs is to ignore the unknown option fields, introduced by DFP, of ISO 8473 NPDU.

Suppose that A3 does not implement DFP. The scenario of migration from 1 to 2 shown in Figure 1 is the same as above.

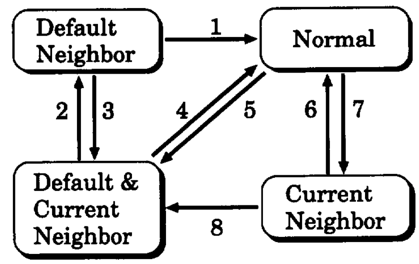

Figure 2: State transition diagram.

1) After A10 becomes adjacent to conventional IS A3, A3 will start to generate and propagate an LSP (3 in Figure 1).
2) On receipt of the LSP from A3, A5 ceases to act as the default NIS of A10.
3) When A10 moves to A5 (4), A5 becomes the default and current NIS of A10 and generates a new LSP including A10's ID instead of sending an *MIG_NTF* to A3 because A5 has already known that A3 does not support DFP.
4) A3 informs the other ISs that A10 has gone by flooding an LSP.
5) In the above situation, PDUs destined to A10 are forwarded toward the default and current NIS A5.

3.4 Procedures of IS

An IS is in one of the four states represented by round boxes in Figure 2 for each ES. Now we describe the procedures of IS according to the state. Note that only normal ISs and the default NIS keep the ES information.

Default NIS: The default NIS of an ES performs the following functions:

1) Upon receipt of an *MIG_NTF*, the default NIS sends an *MIG_ACK* to the sender and extracts the ES information from the PDU, then keeps the information in the ES information base.
2) When receiving a PDU destined to the ES, the default NIS constructs an *FWD_NPDU* from the original PDU and forwards it to the current NIS. If it has no ES information corresponding to the ES, it discards the PDU.

3) When receiving an LSP including the ID of the ES, the default NIS enters the Normal State generating an LSP which does not include the ID of the ES (the arrow 1 in Figure 2).

4) The default NIS may enter Normal State if it wants to do so because of the overload, out of memory or something else. (the arrow 1).

5) When receiving an *FWD_NPDU* from the current NIS, the default NIS eliminates the ES information and enters the Normal State (the arrow 1).

6) The default NIS enters the Default and Current Neighbor State after ES moves to itself (the arrow 3).

7) The default NIS generates an LSP including the ID of the ES even if the ES is not adjacent to it.

8) Entering the other state, the default NIS removes the ES information from its ES information base.

The action of 5) is required for the case that the ES rapidly moves from one IS to another IS and *MIG_NTF*s reach in the reverse order.

Current NIS: The current NIS of an ES performs the following functions:

1) The current NIS does not have the ES information.

2) The current NIS sends an *MIG_NTF* to the default NIS to notify that the ES has moved to it. It retransmits the *MIG_NTF*, if it does not receive an *MIG_ACK* in a regular time.

3) The waiting timer for an acknowledgment expires without receiving an *MIG_ACK*, the current NIS enters the Default and Current Neighbor State (the arrow 8 in Figure 2).

4) The current NIS may enter the Default and Current Neighbor State if it wishes, even if there is already the default NIS (the arrow 8).

5) On ES's Hello timer expiration, the current NIS becomes a normal IS (the arrow 6).

6) On receipt of an *FWD_NPDU* destined to itself, the current NIS reconstructs the original NPDU from it, then hands it to the ES.

7) If an *FWD_NPDU* addressed to another IS is received and the original destination address of the PDU is the ES, the current NIS reconstructs the original NPDU from it and passes it to the ES. If it receives an ISO 8473 NPDU destined to the ES, which may be on the way to its default NIS, it may pass the NPDU directly to the ES. We call these actions *interception* by the current NIS.

8) The current NIS may generate and send an *INF_NPDU* adding the ES information to the original data NPDU.

Default and current NIS: The default and current NIS of an ES performs the following functions in addition to the function 7) of the default NIS and the functions 1), 6), 7) and 8) of the current NIS:

1) When the ES's Hello timer expires before an *MIG_NTF* is received, the default and current NIS enters the Normal State, generating an LSP which claims that the ES is not a neighbor of it (the arrow 4 in Figure 2).

2) The default and current NIS enters the Default Neighbor State when the ES moves to another IS (the arrow 2).

3) The default and current NIS may enter the Normal State instead of the Default State when the ES moves to another IS (the arrow 4), although this state transition is the same as IS-IS and results in increasing traffic.

Normal IS: A normal IS performs the following functions:

1) A normal IS enters the Default and Current Neighbor State if it notices a new neighbor ES and there is no IS propagating an LSP which concludes the ID of the ES (the arrow 5 in Figure 2).

2) A normal IS enters the Current Neighbor State if it notices a new neighbor ES and there is an IS propagating an LSP including the ID of the ES (the arrow 7).

3) If an *FWD_NPDU* addressed to itself is received, then it overwrites the destination address field to the default NIS or the default and current NIS and sends it.

4) A normal IS may cache ES information contained in the DFP PDUs in its ES information base. It may also construct and forward an *FWD_NPDU* from an NPDU according to the cached ES information. A normal IS can cache ES information if and only if it does not have corresponding ES information or it can decide that the received ES information is newer than that in its ES information base based on the following decision rules:

Decision rules: In any of the following cases, the receipt ES information is newer than the cached ES information.

(a) The receipt NPDU is any of *MIG_NTF*, *MIG_ACK* or *INF_NPDU*.

(b) The receipt NPDU is *FWD_NPDU* and its source is the default NIS.

(c) The receipt NPDU is *FWD_NPDU* and its source is the same as the current NIS of the corresponding ES information in its ES information base.

5) Except the cases of 3) and 4), it forwards an *FWD_NPDU* according to the destination address of it without overwriting the address and also without caching the ES information.

We introduce the above decision rules because of the following reasons: Control PDUs exchanged by ISs include no information to decide the order of the information, such as time stamps or sequence numbers. For use of time stamps, it needs to synchronize every IS's clock in the area but it is generally difficult or costs so much. Further, the protocol is required not to have ES do special functions, hence it must be an IS to assign a sequence number, but it is hard for the IS to assign an appropriate number.

Even if there is obsolete information in the area, no loop occurs and ISs can forward NPDUs to the right destination. We will discuss closely this point in the next section.

4 Evaluation

Total traffic: Let us compare the traffic of DFP and of IS-IS. Let $\mathcal{I}$ be the set of ISs and C be the number of level 1 circuits in the area. Let the distance of $i_1, i_2 \in \mathcal{I}$ be $d(i_1, i_2)$ and the mean distance of two ISs be

$$H = \sum_{i_1 \in \mathcal{I}} \sum_{i_2 \in \mathcal{I}} d(i_1, i_2) / \mid \mathcal{I} \mid^2 .$$

We assume that the data traffic and the migration occur at random and are limited within an area, each of them is exponentially distributed with means μ and λ respectively. The transmission delay and the time interval of LSP transmission are not taken into account.

Table 1 shows the number of PDU hop with one data transmission and the number of control PDU hop with one migration using DFP and IS-IS respectively. Hops between the ES and the IS are not counted and the effect of caching and interception is not considered in the communication of DFP.

From this table, it is obvious that DFP is more efficient about control PDUs than IS-IS and IS-IS is better than DFP about data PDUs. As C increases, i.e., new circuits are available, the value of H decreases and DFP gains more advantage concerning the number of control PDUs against IS-IS. In regard to the traffic of data PDUs, DFP can reduce the difference by virtue of caching and interception described in section 3. However these effect are not presented in a simple expression because it concerns network topology and route selection.

We then evaluated the effect of caching and interception by simulation. The communication rate λ of an ES is a constant 1 (PDU/s) and the rate of migration μ increases. The network topology is based on Figure 1 ($C = 6$ and $H = 1.12$) and we assume all ISs implement DFP and the number of ES is 10. The data traffic of IS-IS, DFP without caching and interception, DFP without caching and DFP are shown in Figure 3. The traffic of IS-IS and that of DFP without caching and interception are obtained by Table 1. The data traffic of DFP is explicitly reduced compared to the analysis owing to the caching and interception.

The total traffic of IS-IS (obtained by Table 1) and that of DFP are shown in Figure 4. We see clearly that the total traffic of DFP increases gradually as compared with IS-IS.

	IS-IS	DFP
Migration	$2C$	$2H$
Communication	H	$2H$

Table 1: Comparison of PDU hop count.

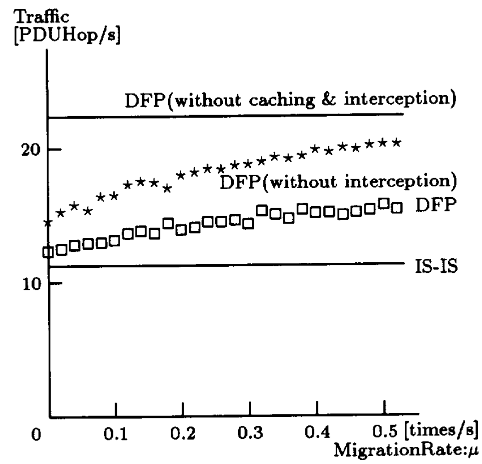

Figure 3: Effect of caching and interception.

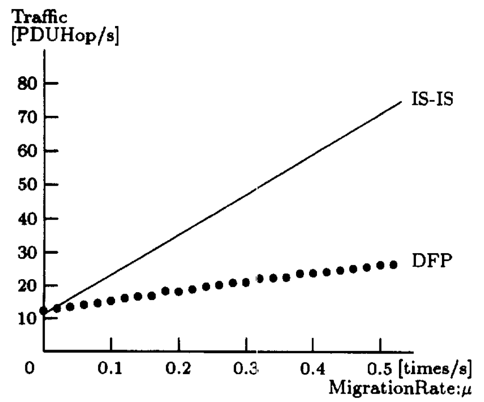

Figure 4: Total traffic comparison.

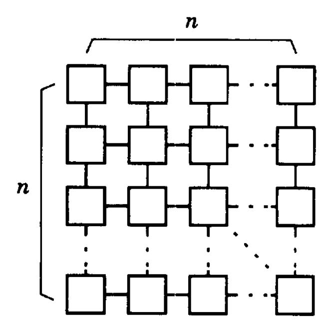

Figure 5: Network topology.

Scalability: Suppose the area topology shown by Figure 5. The area is scaled by an integer n. We see that

$$C = 2n(n-1),\ H = \frac{2(n-1)(n+1)}{3n}$$

and the traffic of DFP (without caching and interception) is $O(n)$ and the traffic of IS-IS (and also the protocol in [1]) is $O(n^2)$ from Table 1. Thus DFP is tolerant to large-scaled networks.

Routing consistency: Although the decision rules of ES information used in DFP do not always decide the order of the two pieces of information, it is easily shown that no loop occurs: Figure 6 illustrates how PDUs are forwarded to the destination ES. The arrow 1 shows a PDU is transmitted through the IS which keeps cache. Then the PDU rewritten its destination address field by the IS reaches the current NIS according to the arrow 8. If the cache ES information of the IS is obsolete, the PDU reaches the previous NIS as shown by the arrow 4. At this time, the previous NIS rewrites the destination address field to the default NIS instead of using cached ES information, then forwards the PDU illustrated by the arrow 6. If a PDU is received according to the arrow 2, the default NIS forwards it to the current NIS presented by the arrow 7. The interception of a current NIS is shown by the arrow 3 and the arrow 9. There are two reasons which may cause the forwarding shown by the arrow 5.

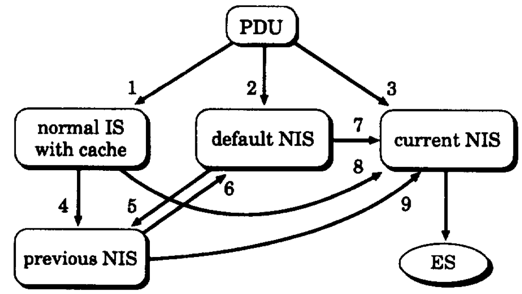

Figure 6: PDU forwarding graph.

1) The current NIS has changed before the PDU reaches the current NIS.

2) *MIG_ACKs* have reached in the reverse order because the ES moved passing by many ISs quickly.

In the case of 2), the previous NIS operates according to the action 5) of the default NIS in clause 3.4. In the case of 1), when the PDU returns to the default NIS by the arrow 6, the default NIS receiving a new *MIG_NTF* will not forward it to the previous NIS again as far as the ES continues to move under delay of migration notification. Thus each PDU reaches either the default NIS or the current NIS by rewritten its address fields at most twice, then there will be no routing loop caused from obsolete caches.

Robustness: Concerning the traffic, DFP is strong for concentration of migration which is expected in practical use. DFP is also robust against congestion, because the routing table of IS-IS maintained by each IS is not changed in each migration. Furthermore, since the default NIS of each mobile ESs can dynamically change, another IS can be an alternative at any time if it goes down.

Quickness of migration notification: As described in section 2, some delay time is expected before LSPs are flooded in an area with IS-IS. Since DFP uses

ISO 8473 NPDUs to notify ES migration, delay time is expected to be small enough.

Unnecessity of ES extension: Hence ISs manage the ES information, ESs do not need to perform any functions besides ES-IS.

Interoperability with the conventional ISs: ISs implementing DFP are interoperable with ISs not implementing DFP if the latter ignores the option fields of NPDUs added in clause 3.2.

Independence from other areas: ES information is exchanged only in the area and the other areas in the routing domain are not affected by the information. There is a possibility that an *INF_NPDU* is sent out of the area but it does not influence other areas if the ISs on the way to the destination and the destination ES ignore the option field. If the ISs which reside at the border of the area remove the field and disable the sending *INF_NPDU* function, then the influence on the other areas will be totally removed.

5 Related works

As mentioned in section 1, previous works such as [2], [6], [7] and [8] are not appropriate for supporting mobile ESs in an area. In addition, mobile ESs should perform additional functions such as migration notification, hence they cannot be directly applied to the existing networks.

The OSI-based protocol proposed in [1] is considered to be a natural enhancement of IS-IS and causes the same problems as IS-IS. It enhances ES's functions as well for the level 1 routing and ISs need information about mobile ESs obtained through the level 1 functions for the level 2 routing, it cannot be therefore adopted for the existing networks.

A caching mechanism was originally employed in [6]. In the original usage, clear packets are broadcasted to eliminate obsolete caches. In DFP, on the contrary, obsolete caches are left without explicitly eliminated, because broadcasting clear packets causes considerable traffic. Alternately, DFP uses the decision rules to determine the order of ES information partially.

6 Conclusion

In this paper, we have proposed DFP which can support mobile ESs in CLNP network environment. Separating the default NIS and the current NIS makes it possible to reduce the number of control PDUs and to shorten the delay of migration notification. The main advantage of DFP is that it does not require any changes to systems in other areas as well as in the area. This makes it easy to apply DFP to existing CLNP networks. DFP is also used in conjunction with the protocol for inter-area migration which we have proposed in [7].

We are trying to apply the basic idea of DFP to the wireless LAN in which mobile ESs are managed by Access Points (APs) instead of ISs. We will implement DFP and then evaluate it in a practical use.

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