Cooperative technique to optimize total allocation time in heterogeneous domains in an Optical Access Network

Shunsuke Kanai*, Akira Inoue, and Hiroshi Uno

NTT Access Network Service Systems Laboratories
1-6 Nakase, Mihama-Ku, Chiba-Shi, Chiba-Ken, 261-0023,JAPAN
TEL:+81-43-211-3204 FAX:+81-43-211-6418
E-mail: {s.kanai, ainoue,uno}@ansl.ntt.co.jp

Abstract

We describe a cooperative technique in heterogeneous domains for allocating the fiber routes in an Optical Access Network (OAN).

There is an Intra-office Optical Distribution Network (I-ODN) in an OAN and its equipment configuration has one characteristic that improves cost efficiency. This is achieved by changing the point where the splitter is installed to cope with increasing demand for Passive Optical Network (PON) service. However, more allocations have to be done with such an equipment configuration than with a conventional one as conventional cooperative techniques do not take cost efficient equipment configurations into consideration.

In this paper, we analyze the current issues in conventional cooperative techniques for allocating fibers. We propose a new cooperative technique that enables allocation time to be shortened even if the point where the splitter is installed is changed with increasing demand for PON service. we prove the effect of the proposed cooperative technique through simulation, i.e., it can shorten the total allocation time by 29% compared with the conventional to deliver rapid and cost-effective services .

Keywords: operations support system, optical fiber, allocation, optical access network, optimization

Contact: Shunsuke Kanai(s.kanai@ansl.ntt.co.jp)

Overview

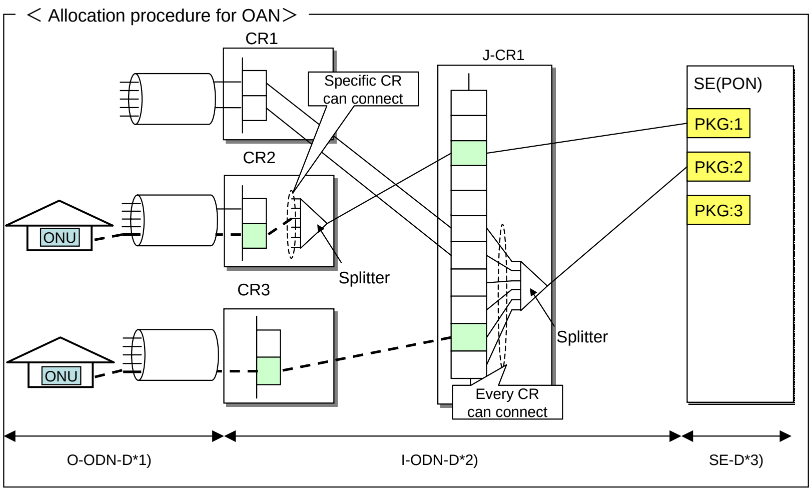

Figure 1. Optical Access Network Configuration

*1) : O-ODN-D=Outside Optical Distribution network Domain
*2) : I-ODN-D=Intra-office Optical Distribution network Domain
*3) : SE-D=Service Equipment Domain

1. Introduction

The number of Internet customers has recently been increasing [1] and many kinds of broadband network services like the Passive Optical Network (PON) service are currently being developed [2]. Moreover, the number of telecommunication carriers has been increasing [3]. This means that telecommunication carriers are being expected to satisfy the demands of customers in order to survive in a competitive market. Therefore, we need to shorten their service provisioning times with cooperative techniques in heterogeneous domains and reduce their service provisioning costs by improving the cost efficiency of equipment configurations.

We developed an Operations Support System (OSS) that achieved efficient management and reduced the total allocation time [4]. This OSS consisted of three management domains, including the Outside Optical Distribution Network Domain (O-ODN-D), the Intra-office Optical Distribution Network Domain (I-ODN-D), and the Service Equipment Domain (SE-D). We needed to separate heterogeneous domains to maintain the uniqueness of data and algorithms [5-7]. Tayama et al. [4] explained that the cooperative technique in heterogeneous domains could reduce the total allocation time, thereby making it possible to provide services immediately by allocating fibers and PKGs with the cooperative technique in heterogeneous domains.

We made some assumptions regarding the OSS. The starting position of allocation depends on the customer's address in an O-ODN. The required SE depends on the service type that the customer applied. However, in an I-ODN, the start and terminal points depend on whether the CR is allocated by the O-ODN-D or the SE is allocated by the SE-D. Therefore, the equipment configuration has to be flexible so that the I-ODN can do allocations effectively. Therefore, a splitter has to be installed in the Junction-CR (J-CR) for the PON (Passive Optical Network) service. The allocation process is completed every time there is a fiber available between the CR and output port of the splitter. Installing a splitter in the J-CR is an optimum configuration that can be used to allocate fibers immediately. Therefore, the conventional cooperative technique for allocation assumes that a splitter has been installed in the J-CR, since fibers can be allocated immediately in the I-ODN.

However, such an assumption is only based on reducing the total allocation time. In particular, I-ODNs decrease cost efficiency if there is an emphasis on allocation policies that reduce this total time for allocation. Therefore, we have to analyze whether these assumptions can be adopted at any time to solve this trade-off between cost efficiency and allocation time.

This paper discusses a technique that resolves the problem with the cooperative technique in heterogeneous domains. Briefly stated, we have addressed the following.

1) What the problem with the conventional cooperative technique is in heterogeneous domains to shorten the total allocation time.

2) Ways the total allocation time can be reduced with a cooperative technique in heterogeneous domains when cost efficiency is emphasized.

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Cost Analysis

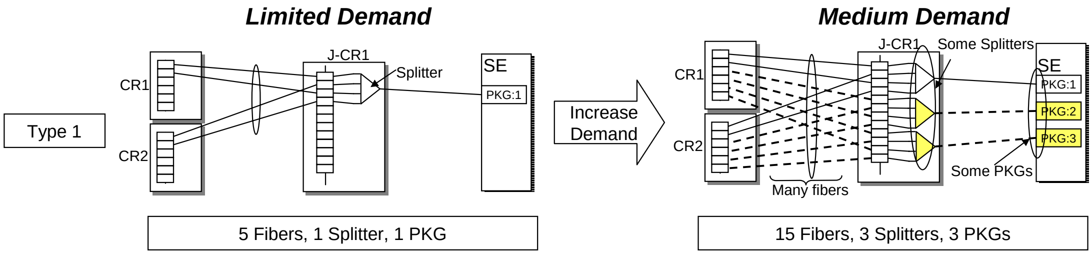

Figure 2. Change in amount of equipment (Type 1)

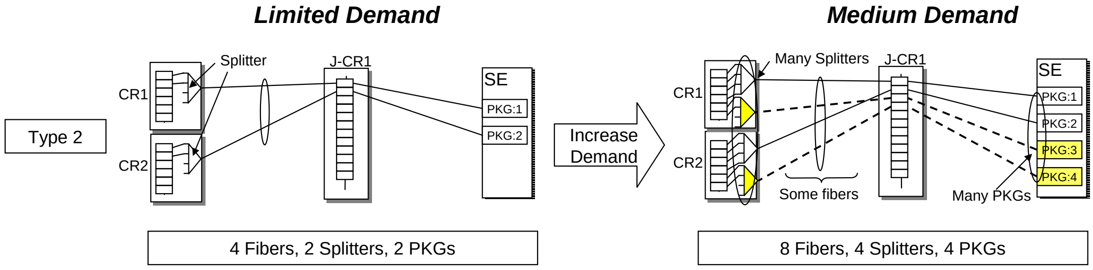

Figure 3. Change in amount of equipment (Type 2)

2. Cost and allocation time comparison with each type

This section discusses whether the cost efficiency and total allocation time for the conventional equipment configurations used in I-ODNs can be improved at any time. We compared two types of equipment configurations. A splitter is installed in a J-CR for Type 1 and it has a conventional equipment configuration that emphasizes immediate allocation. A splitter is installed in a CR for Type 2. Cost efficiency depends on the amount of equipment. We therefore analyzed the amount of equipment (fibers, splitters, and PKGs) to compare costs for limited and medium demand (2-1). After that, we analyzed the total allocation time for each demand (limited and medium) (2-2). We then analyzed the results we obtained in the two comparisons (2-3).

2-1. Cost analysis

a) Figure 2 shows the change in the amount of equipment for Type 1.

When demand is limited, it is not necessary to construct many fibers between the CR and J-CR. However, when demand reaches medium, this type requires numerous fibers between the CR and J-CR since the PON service shares a fiber between the PKG and the input port* of the splitter, and this fiber is distributed by the splitter. Therefore, more fibers are required between the output port* of the splitter and the CR.

b) Figure 3 shows the change in the amount of equipment for Type 2.

It needs more splitters and PKGs than Type 1, because it is necessary to install splitters for each CR and PKG in the SE with increasing demand. The rate of splitter use is low for this type. When demand occurs each CR (CR1 and CR2), for Type 1 can only connect one splitter in the J-CR for each demand, but Type 2 has to connect two splitters in each CR for each demand. However, as a splitter has been installed in each CR, the number of fibers between the CR and J-CR does not increase more than it does for Type 1.

As a result, when demand increases, Type 1 needs more fibers than Type 2 and the latter needs more splitters and PKGs installed than the former.

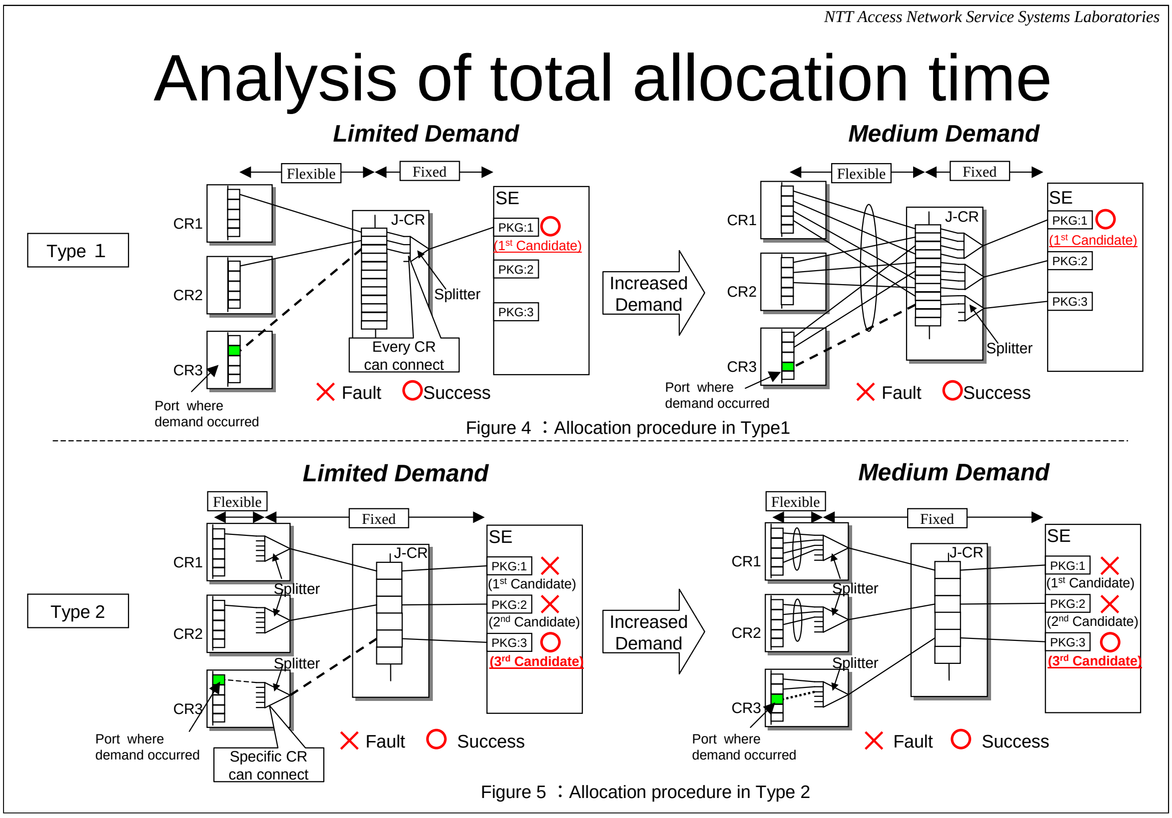

Figure 4 ：Allocation procedure in Type1

Figure 5 ：Allocation procedure in Type 2

2-2. Analysis of total allocation time

a) Figure 4 shows the allocation procedure for Type 1.

This can finish allocating in only one database retrieval through having had a splitter installed in the J-CR even if demand occurs in any CR. Moreover, it can maintain the total allocation time even if demand increases. If a PKG that provides a service becomes occupied in allocating services to a customer, this PKG will be out of candidature in the next allocation and will not be permitted to allocate. After a new PKG has been installed, it will be allocated as a new candidate.

b) Figure 5 shows the allocation procedure for Type 2.

This type increases the total allocation time with increasing demand. If demand occurs in CR3, allocation fails and the next candidate needs to be allocated. This is because, the SE-D allocates PKGs from the smallest number (1st, PKG:1 2nd, PKG:2, and 3rd, PKG:3). SE needs to give priority for use and allocation from the smallest number of PKGs to improve cost efficiency as these are expensive. An PKG is allocated by the SE-D and the fiber between the CR and PKG is allocated by the I-ODN-D. Therefore, if allocation fails many times in Type 2, it needs many allocation and sending and receiving processes in each domain. Moreover, such a long total allocation time is sustained after increasing demand. However, the rate of success in allocation depends on where the CR has been allocated by demand. If demand occurs in CR1 (Fig. 5), the allocation process will finish after only one database retrieval (least). However, when demand occurs in another CR, the allocation process will fail after more than one database retrieval. Therefore, the total allocation time for Type 2 depends on where the CR has been allocated by demand.

Type 2 can improve the rate of successful allocation according to changes in the allocation procedure. When a second demand (1) for PON service occurs in the CR, it can allocate by searching for a splitter in the CR and identifying the fiber route between the splitter and the PKG that has been already provided by the first demand (2). When it can identify the SE allocated by SE-D, allocation finishes immediately. However, because many kinds of PON services have been developed, they have needed different types of SE with many splitters in the CR to connect them to the PKG, Therefore, if such a technique is adopted, many processes will be required to search for splitters and identify the fiber route. These processes increase more than with the conventional allocation procedure with increasing numbers of SE. Therefore, these are not suitable techniques in improving the rate of successful allocations.

As a result, when demand increases, Type 1 can finish allocating in a minimum time, but Type 2 needs more time.

Comparison of results

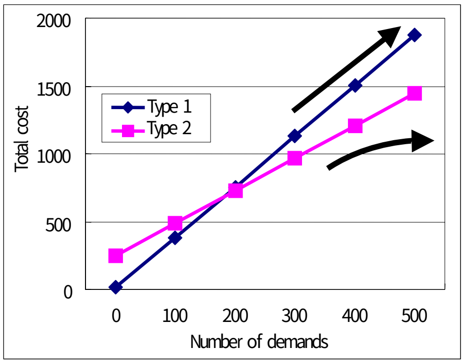

Figure 6 : Comparison of construction costs

	X	Y	Z
Type-1	$Roundup(D/S,0)+D$	$Roundup(D\times n2/S,0)$	$Roundup(D\times n2/S,0)$
Type-2	$Y\times 2$	$Roundup(D\times n1/S,0)\times n1$	$Roundup(D\times n1/S,0)\times n1$

X : Number of fibers
Y : Number of Splitters
Z : Number of PKGs
*Total Cost = c*X+s*Y+p*Z*
D: Number of demands
n1:Number of CRs with splitter
c : Cost of fibers
s : Cost of splitter
p : Cost of PKG
S: Number of distribution splitters
n2:Number of J-CRs with splitter

[*Rounudup: Rounds a number up, away from zero*] Price comparison : *c:s:p=1:5:5*

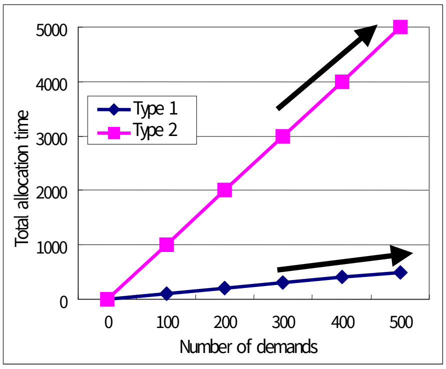

Figure 7 : Comparison of total number of times to allocate

	Number of allocations for one demand
Type-1	One time
Type-2	$\frac{\text{Number of All PKGs}}{2}$ =10 times

Number of all PKGs	: 20
Number of PKGs with successful allocations	: 10
Time to allocate once	: 1
Time to send and receive once	: 1

2-3. Comparison of results

We compared the cost efficiency and total allocation time with each type.

a) Figure 6 has the results of comparing construction costs.

We extracted the amount of equipment (fibers, splitters, and OUSs) for each demand. We then calculated the total cost using the unit cost for each piece of equipment. The variations in these costs for each demand with Type 1 and Type 2 are plotted in Fig. 6.

--Analysis of results in comparison--

Type 1 is cost effective in the early stages (limited demand). However, after this (medium demand), cost efficiency decreases with increasing demand because its fiber costs increase more than for Type 2. Although Type 2 needs higher initial costs, its cost efficiency is better with increasing demand and it can maintain lower fiber costs. As a result, cost efficiency can be improved by changing the splitter position from J-CR to CR.

b) Figure 7 plots the total allocation time against the number of demands for Types 1 and 2.

We defined the number of allocations in Type 1 as one because allocations can be successfully done by installing a splitter in the J-CR even if demand occurs in any CR. We also defined the number of allocations in Type 2 (number of all PKGs/2) because this depends on the CR where demand occurs. We therefore defined the number of allocations in Type 2 as the average number in all PKGs.

We found that Type 2 needs numerous database retrievals to allocate with increasing demand while Type 1 only needs a minimal number.

As a result, when demand increases, Type 1 has low cost efficiency, but its total allocation time is very short. In contrast, Type 2 has high cost efficiency and its total allocation time is very long.

Current issues and goal

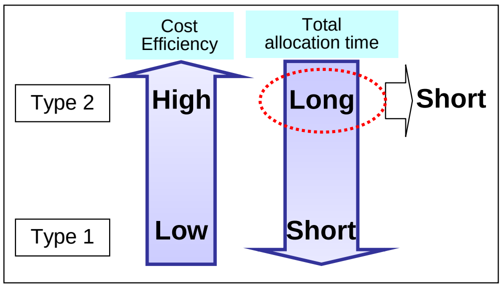

Figure 8 : Trade-off between Types 1 and 2

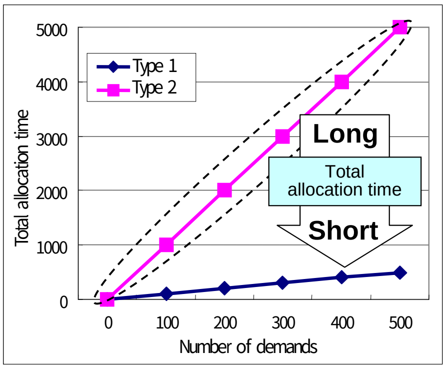

Figure 9： Our goal

3.Current issues and our goal

We found that there was a trade-off between Types 1 and 2 (Fig. 8) in terms of cost efficiency and total allocation time. When demand increases, Type 1 has low cost efficiency, but it needs a long allocation time. Type 2 can allocate in a short time, and it has high cost efficiency.

We established a goal to resolve these issues, which is outlined in Fig. 9. We can see that Type 1 has a problem where many fibers are needed when demand increases. To solve this, we had to find out how to reduce fiber costs to gain cost efficiency. We therefore analyzed new cooperative techniques in heterogeneous domains to reduce both the total allocation time and improve the cost efficiency for Type 2 when PON demand increases.

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Identifying causes

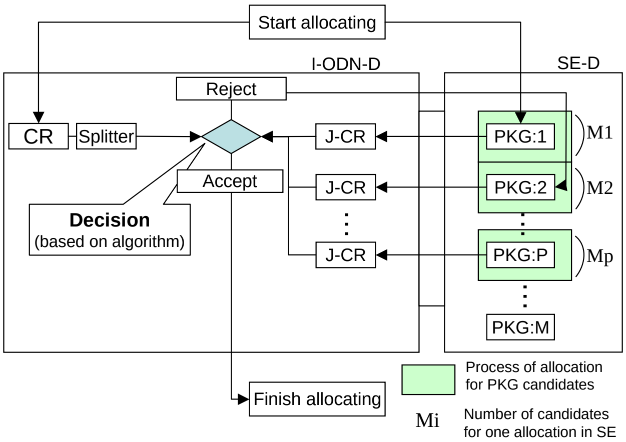


Figure10 : Conventional method of allocation for PON (Type 2)

	Number of times to send & receive	Number of times to allocate for PKG
PKG candidates =ONE	Most	Least
PKG candidates =ALL	Least	Most

Figure11 : Number of times in each process

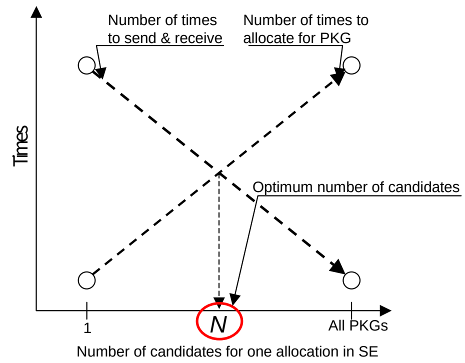


Figure12 : Optimum number of candidates to allocate

4. Identifying causes

This section discusses how we have established a technique to reduce total allocation time. First, we explain the allocation process and the conventional cooperative technique in heterogeneous domains for allocation. We then identify what we have to analyze to reduce total allocation time.

a) Figure 10 shows the conventional cooperative technique in heterogeneous domains for allocation in PON (Type 2)

Process of allocation in heterogeneous domains

a-1) : Start allocating (order of transmission with number of candidates to be allocated once)

a-2) : PKG is allocated in SE-D

a-3) : Send the results of allocation to I-ODN-D

a-4) : Fiber route (CR <-> Splitter <-> J-CR <-> PKG) is allocated in I-ODN-D

a-5) : Allocation failure (Decision to “reject”): The SE-D receives an order from I-ODN-D to re-allocate. The next candidate is allocated in the SE-D

a-6) : Allocation success (Decision to “accept”): finish allocating

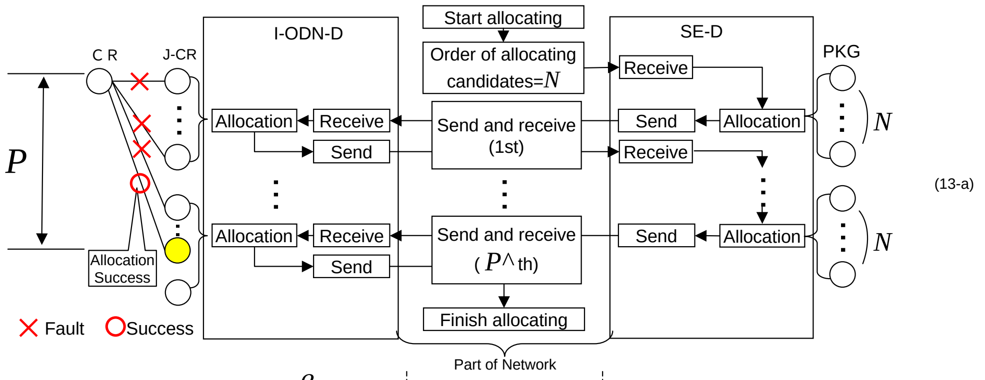
The conventional method is based on the assumption that the splitter is installed in the J-CR. We therefore decided to establish one PKG candidate to allocate once in the SE (Mi = 1). However, although this had the least allocations, the send and receive information on the PKG candidate had to be transmitted many times to allocate (a-3) or the order to reallocate (a-5) could be transmitted in heterogeneous domains if allocation failed many times. Conversely, if the number of allocation candidates was set to the number of all PKGs installed in the SE (Mi = M), the number of times that send and receive information on the PKG candidate was transmitted to allocate (a-3) or the order to reallocate (a-5) was transmitted were both minimized because they were sent only once. However, many allocations were required, since all PKGs were assigned additional PKGs if allocation succeeded in the Pth number of candidates.

b) Figure 11 shows the number of times send and receive information was transmitted and how many PKGs were allocated and Fig. 12 has our target to solve the problem.

There is a trade-off where one or all candidates are allocated. A reduction in the number of times send and receive information is transmitted causes an increase in the PKGs that are allocated. Conversely, a reduction in the number of PKGs allocated causes an increase in the number of times send and receive information is transmitted. This means that there is an optimum number of candidates that minimizes the total allocation time in all numbers of candidates and we need to do analysis to determine this number.

Because there is an optimum number of candidates that minimizes the total allocation time (sending, receiving, and allocation time) in heterogeneous domains, we analyzed a new cooperative technique, taking the minimization of total allocation time into consideration.

Proposed technique



	β	α	γ
Allocation time	$P \times \varepsilon$	—	P^$\times N \times \delta$
Send & receive times	P^$\times \varepsilon'$	P^$\times \phi$	P^$\times \delta'$
Total allocation time	$P \times \varepsilon + P$^$\times \varepsilon'$	P^$\times \phi$	P^$\times N \times \delta + P$^$\times \delta'$

(13-b)

$$\mathrm{T}(N) = \alpha + \beta + \gamma$$

(13-d)

$$P\text{^} = Roundup(P/N, 0)$$

φ : time to send and receive once (NW)
ε : time to allocate once (I-ODN-D)
δ : time to allocate once (SE-D)
ε' : time to send and receive once (I-ODN-D)
δ' : time to send and receive once (SE-D)
13-c

<Figure13 : Allocation time & send and receive times in heterogeneous domains>

5.Proposed technique

This section discusses how we found the optimum number of candidates, which enabled us to minimize total allocation time (sending, receiving, and allocation time) in heterogeneous domains (5-1) and to derive the new cooperative technique we propose (5-2).

5-1. How to calculate optimum number of candidates to minimize total allocation time

1) Assumption

We defined the allocation procedure in heterogeneous domains (I-ODN-D, NW, SE-D). The order of allocation is transmitted from a remote computer with an operator via the NW to the SE-D, holding the number of candidates for allocation once (Fig. 13-a). When allocation is completed in the SE-D, the PKG candidates are transmitted to the I-ODN-D via the NW. When allocation fails in the I-ODN, the order of re-allocation is transmitted to the SE-D and executed. Such processes are continued until allocation is successful in the I-ODN-D. When this occurs, information on successful allocation is transmitted to the remote computer used by the operator via the NW from the I-ODN-D.

2) Method to calculate allocation and send and receive times.

Total allocation time consists of allocation times and send and receive times. These can be calculated by the number of times and unit time once. We have defined unit time in Fig. 13-c. To calculate the total allocation time, we need to identify the allocation times (*P*) and send and receive times (*P*^) in heterogeneous domains (Fig. 13-a).

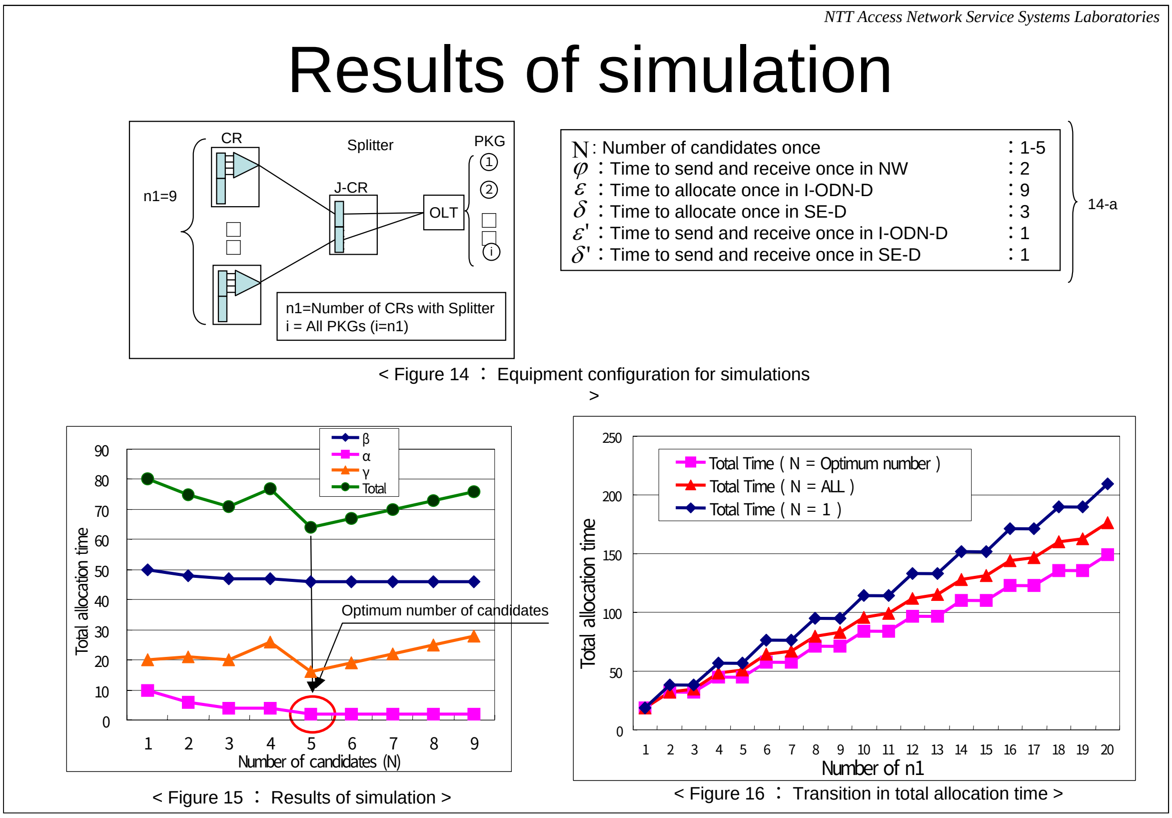
P is the number of average allocation times between allocation start to success in the I-ODN (Fig. 13-a). It is possible to calculate *P* from expectations of probability and these can be calculated with PKG data. (Details on the calculation formula are in Appendix 3). *P*^ is the number of transmissions (send and receive) in heterogeneous domains. *P*^ can be calculated by [*P*^=Roundup (*P/N*, 0)* Rounds a number up, away from zero]. The total allocation time in the I-ODN-D and SE-D can be calculated using *P* and *P*^ and the number of candidates (*N*) (13-b). Therefore, the total allocation time in the OSS can be calculated with *T(N)* (Fig. 13-d). In other words, we can identify the optimum number of candidates (*N*) that minimize *T(N)* in heterogeneous domains.

5-2. Proposed new cooperative technique

1) Cooperative allocation technique using optimum number of candidates

It is possible to identify the number (*N*) of candidates that minimizes the total allocation time (*T (N)*) before allocation. Therefore, the operator can specify the number of candidates before s/he sends the order of allocation. The number of PKG candidates "*N*" that are allocated in the SE-D are transmitted to the I-ODN-D via the NW. When allocation fails, an allocation request is transmitted to the SE-D via the NW again. When allocation finally becomes successful, information on allocation is transmitted to the remote computer used by the operator via the NW from the I-ODN-D.

As a result, it is possible to prove the efficiency of the new cooperative technique in heterogeneous domains. This shortens the allocation, sending, and receiving times through the optimum number (*N*).



6. Results of simulation

This section confirms the effect of the proposed new cooperative technique through simulation results.

1) Simulation method

This simulation involved the following. The first was that we could specify the number of candidates that minimized allocation time, when the number of allocation candidates (*N*) changed sequentially within a specific equipment configuration. The second was that we could specify the total allocation time in each number of n1.

Figure 14 shows the equipment configuration for simulation.

Figure 14-a shows the set-up parameter values for this simulation.

2) Simulation results

Figure 15 shows the transition in total allocation time from *N*=1 to *N*=9 [when the number of candidates changed from 1 to 9 (9= maximum number of PKGs). We can see that the number of candidates that minimizes total allocation time is *N*= 5.

Figure 16 shows the transition in total allocation time for each number of candidates. Here, for *N* =1, we have to spend a lot of time in allocation with an increasing number of n1. When *N* = ALL (maximum number of PKGs), the time required for allocation with an increasing number of n1 increases compared with *N*=Optimum Number. This means that the optimum number of candidates calculated with the proposed method can shorten the total allocation time in every number of n1.

Conclusive results

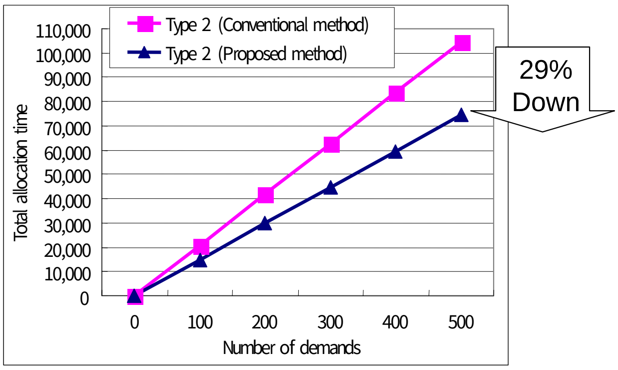


Figure 17 ： Evaluation of proposed method

	0	100	200	300	400	500
Total allocation time for Type 2 (Conventional method)	0	20,900	41,800	62,700	83,600	104,500
Total allocation time for Type 2 (Proposed method)	0	14,900	29,800	44,700	59,600	74,500

7. Conclusive results

Our goal was to shorten the total allocation time for Type 2. That is, to decrease the total time for allocations. We therefore proposed a new cooperative technique in heterogeneous domains. The operator can identify the optimum number of candidates that will minimize the total allocation time. We will first explain the assumption we used in evaluating the results in (a). We will then analyze the results of evaluating the proposed method in (b).

(a) Assumption for evaluation

We calculated the total allocation time for each demand for each type. We identified the total allocation time for each type when n1 was 20 by referring to the results in Fig.16, and we then calculated the total allocation times for each demand for each type. We defined the number of candidates with the conventional method as $N = 1$.

(b) Evaluation of results

Figure 17 shows the results of evaluating the proposed method. After comparing the transition for the “Proposed Method” and “Conventional Method”, we can see that the former is superior and simulation revealed that it could allocate 29% faster than the conventional method, shortening the total allocation time.

Conclusion and Future Work

- Conclusion
  - Cost efficiency in an I-ODN improves by moving splitter position at installation with increasing demand for PON service.
  - Total allocation time can be reduced by changing the number of PKG candidates
- Future Work
  - Improve efficiency of allocation algorithm in heterogeneous domains

8. Conclusion and Future Work

Here, we emphasized the need for a cooperative technique in heterogeneous domains that enables quick and cost-effective allocations. The problem with the conventional cooperative technique has been that the equipment configuration in the I-ODN, which enables improved cost efficiency, has not been taken into consideration. We described a cooperative technique that satisfies this need. It identifies the number of optimum candidates by calculating the allocation times (*P*) and the number of transmissions (*P^*).

We clarified the effect the proposed cooperative technique had through simulation. We found that it reduced the total time of allocations by 29% compared with the conventional cooperative technique. As a result, it enabled us to deliver quick and cost-effective services.

As future work, we intend to increase the efficiency of the allocation algorithm in heterogeneous domains, and reduce the allocation time in heterogeneous domains.

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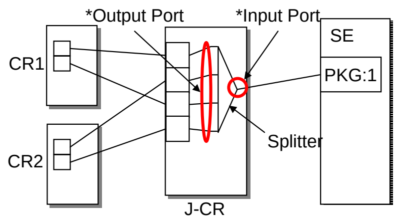
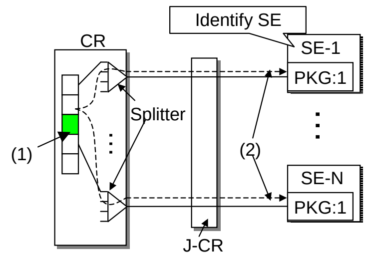
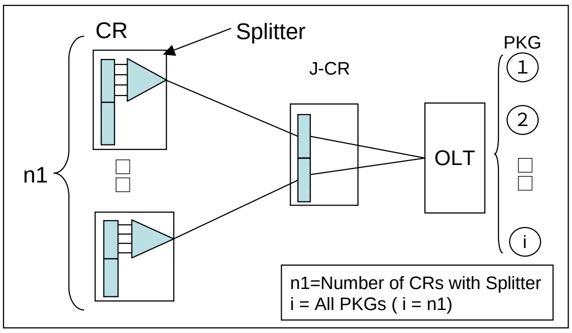
Appendix



Appendix 1 : The position of input and output ports



Appendix 2 : Another allocation procedure



Appendix 3 : How to calculate P

Appendix 3 : How to calculate P

This describes the process to calculate P. First, we have to calculate the probability of successful allocation for each PKG (2). Then , we have to calculate the expected average allocation time (3).

To obtain the probability of successful allocation for each PKG (= i), we need two probabilities. The first is the probability of allocating one PKG where it is possible for the allocation process to succeed for all PKGs (1-1). The second is the probability of failed allocation until i-1 times (1-2).

(1) Probability of allocation success

(1-1) The probability of allocating one PKG where it is possible for the allocation process to succeed for all PKGs (=n1-(i -1)).

$$F_i = \frac{1}{n1-(i-1)}$$

(1-2) Probability of failed allocation until i-1 times

$$G_i = \prod_{i=1}^{i} (1 - F_{i-1})$$

(2) Probability of successful allocation for each PKG (= i)

$$P(a_i) = G_i \times F_i$$

(3) Expected average allocation time

$$P\,(n1) = \sum_{i=1}^{i} \left(i \times P(a_i)\right)$$