Kerberized LeaSel Model for Grid

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Summary
Rapid advancements in hardware have fostered the growth of Grid computing. Grids, formed from interconnection of clusters, provide behemoth amount of computing power. The technology assumes importance due to its ability to tap the unused computing power available in the distributed environment. Such a heterogeneous milieu is plagued by security concerns. Secure Group communication in the grid is a potentially critical concern with a broad scope for addressing the needs of a number of applications. Recently, it has come under the microscope of the researchers. Efforts have been made on proposing a highly secure, distributed, scalable and computationally efficient model for group communication in the grid environment. The proposed multicast security model satisfies the diverse security requirements of the multicast grid applications. The model is an adapted and strengthened version of LeaSel model, already proposed and proven for wired and Mobile networks. Kerberos is used for authentication.

Key words:
Grid Computing, G-LeaSel, Kerberos and Multicast Network Security.

1. Introduction

The Grid is a collection of resources (processors, storage devices, peripherals etc) which may be used, shared by several applications to compute faster and more efficiently. The goal here is to create a simple, large, powerful and self managing virtual computer out of a large collection of connected heterogeneous systems sharing various combinations of resources, as put across in [3]. [8] Provides a three point checklist to determine the class of systems that can be grouped under the term ‘grid’. An environment with widely distributed resources such as the grid is prone to various types of security attacks, since applications may involve migration of code between the various sites. Thus, security assumes a role of vital importance in grid [12]. Collaborative grid applications involve multiple users who co-operate together on a single shared task. Such applications can use multicasting to transmit the same data to a group of users. By using efficient multicast routing protocols, the network load can be minimized in such a scenario of one to many transmissions. Category of grid applications that may be referred to as “wide-area distributed computing” need Multicast as well as very high computational power. Grid is the best source for relatively cheap and enormous computational power. For example, [7] quotes several applications like Computational Steering [13], Video Conferencing and Online Network Gaming. The LeaSel model has already been adopted successfully to support Online Network games [5]. The stringent security needs of collaborative grid applications necessitate the development of a secure multicast security model exclusively for grid.

Section 2 explicates the existing security features of grid. Section 3 proposes the G-LeaSel multicast security model. The Kerberos authentication for G-LeaSel is explained in section 4. The group formation scenarios are explained in section 5. Section 6 deals with the membership algorithms. The experimental results are presented in section 7 and the paper is concluded in section 8.

2. Existing Security Features of Grid

Security in grid, is now provided by two mechanisms, namely GSI (Grid Security Infrastructure) and Kerberos. GSI, which is explained in detail in [9], [14], [15], is based on PKI (Public Key Infrastructure). It requires the two entities in communication to mutually authenticate those using Digital Certificates, before communication can commence. After the mutual authentication is over, GSI moves aside and the communication can then be secured using a shared secret key. On the other hand, Kerberos [11] is a network authentication protocol. It is designed to provide strong authentication for client/server applications by using secret-key cryptography. It enforces a stringent authentication mechanism by providing users with authenticator, after initial authentication process. Once the client is authenticated, the TGS (Ticket Granting Server) provides access to the service using a ticket. Interoperability can also be provided between GSI and Kerberos [10]. Both GSI and Kerberos emphasize on the Single-sign on feature.

3. G-LeaSel

The LeaSel model [1] [3] is a scalable, secure and distributed security model for group communication. The model reduces the amount of multicast services affected by entity failure, due to its distributed nature [6].After initial authentication by the Controller; the member is allocated to a subgroup under a Deputy Controller. The deputy controller decides the rank of all the members in the subgroup. The first ranked member is designated as the Leader and is entrusted with the responsibility of key generation and distribution. The deputy controller alone knows the identity of the leader and sender anonymity is achieved by hiding the identity of the leader from the other members of the sub group. The deputy controller is also empowered to change the leader dynamically, to make the model more secure.

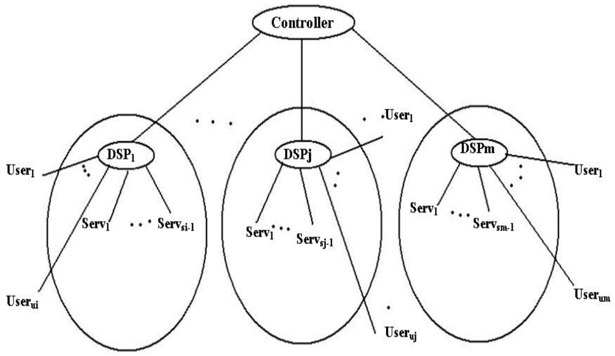

Fig. 1. G-LeaSel Multicast Security Model for Grid.

G-LeaSel, an adaptation of the LeaSel model for the grid, is proposed to provide secure multicast communication services. The gestation of G-LeaSel from LeaSel involves taking a service-oriented approach to the problem. G-LeaSel is a highly secure, dynamic, distributed sub group model, which caters to the needs of the group communication in grid. The model aims to address issues like forward confidentiality, backward confidentiality, scalability, fault tolerance and computational efficiency. The group of 'n' nodes is split into 'm' subgroups, based on the service-classes, as shown in Fig. 1, such that

$$\Sigma\, si = n$$

where i=1 to m and si = no of service-offering nodes or service nodes in the i^{th} subgroup.

The group formation is dynamic. New users can join the group to get the services and users may also leave the group. So the actual number of nodes in the ith sub-group can be expressed as

$$si + ui$$

where i= 1 to m and ui is the number of service-requesting nodes or user-nodes in the i^{th} sub group.

One node is designated as the Controller (C) and it provides the overall multicast security service. 'm' Service providers, one from each sub group, are designated as Deputy Service Providers (DSP). DSPs provide access to all other services under them. They rank the other $s_{i\,+}\, u_i$ - 1 members of the sub-group$_i$ and select a highest ranked node as L_i, the leader of the sub-group$_i$. The Controller and the DSPs share a common group key GK. Each subgroup has a common subgroup key SK_i. Each node has its own private key; PK. There is a GACL (Group access control list) at the controller, which is used for storing details for authenticating users, user private keys and other pertinent details. The controller distributes parts of GACL as SACL (Sub group Access Control List) to the DSPs, which use it also for determining if a user is eligible for a service. Each node is also provided with a key generation module (KGM) and the leader's KGM would be used to generate the sub-group key. The leader is responsible for encrypting and decrypting all data within the subgroup. The identity of the leader is kept secret, known only to the DSP which selects it. The leader is dynamically selected. Hence, G-LeaSel nullifies the chance of the hacker easily attacking the key generating node, since the identity of the Leader is not revealed.

4. Plugging Kerberos into G-LeaSel

LeaSel model [1] does not have any special mechanism for authentication. But adaptation of the model for an environment such as the grid entails a secure authentication protocol. Kerberos [11] can be plugged in as the authentication protocol into the G-LeaSel model. This would strengthen the security of the G–LeaSel model, providing robust authentication and also provide Single Sign-on feature reducing the workload of the Controller. What makes Kerberos the automatic choice is that the entities used in Kerberos can be mapped exactly to respective entities in G LeaSel. Here, the functions of Authentication Server (AS) and Ticket Granting Server (TGS) are vested with the Controller and the Deputy Service Providers respectively. The sturdiness and the level of security of Kerberos are already proven. Thus, plugging in Kerberos to G-LeaSel improves the security of the model vastly with minimal additional complexity.

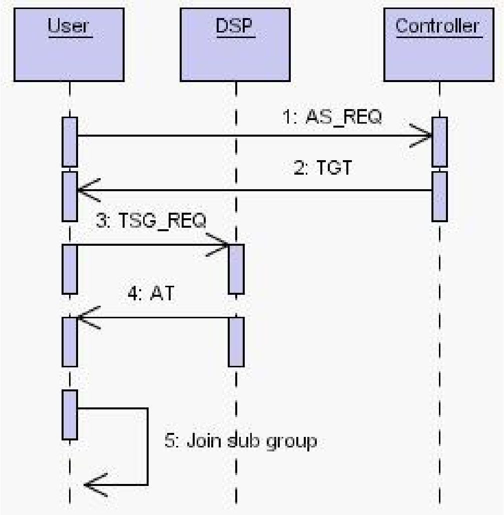

Fig. 2. Authentication using Kerberos

The authentication procedure for G-LeaSel model using Kerberos is presented in Fig. 2. The user requests the Controller for a Ticket to a Deputy Service Provider that hosts the required service (AS_REQ). The controller authenticates the user and returns the Ticket Granting Ticket (TGT) that permits the user to communicate with the DSP. The user requests the DSP for the appropriate service using the TGT (TGS_REQ). The standard Kerberos mechanism is slightly modified here to suit the needs of G-LeaSel. In case of standard Kerberos, obtaining a service involves getting a TICKET to the host providing the security. Obtaining multicast services in G-LeaSel involves joining the subgroup and holding the sub group key. DSP verifies with the SACL and sends an Approval

Ticket (AT). The DSP initiates the KGM of the Leader of the subgroup and the leader distributes the new sub group key.

5. Group Formation Scenarios

G-LeaSel embarks on a different approach to group formation. The group scenarios are chosen such that they reflect the varied needs of the multicast applications over the grid. Each scenario depicts a group of users requesting a set of services from a DSP. The scenarios for group formation are identified as follows.

Scenario 1: u$_i$ user-nodes in the sub-group, request for services to the DSP. Here, the services are available with the DSP and the message transfers are confined to the sub-group

Scenario 2: u$_i$ user-nodes request for services that are not available under the DSP. DSP, in turn, acts as a moderator between user and another DSP that actually hosts the requested services. This scenario is typical of the grid environment, where the service is available elsewhere and an intermediate node acts as a broker to get the service. G-LeaSel handles the second scenario, splitting it into two sub-scenarios (2a, 2b).

A. Services under Single DSP (Scenario 1)

Here, u$_i$ users request services from the DSP$_i$ and the services are available within the sub group. A multicast group is formed, which includes the DSP, the user-nodes and the service-nodes under the DSP as shown in Fig. 2. This scenario satisfies service needs of only those users, who were allotted initially to that sub group. The number of user-nodes obtaining the services is a fraction of the total number of user-nodes. The Leader selection process ensures that sender anonymity is preserved during communication.

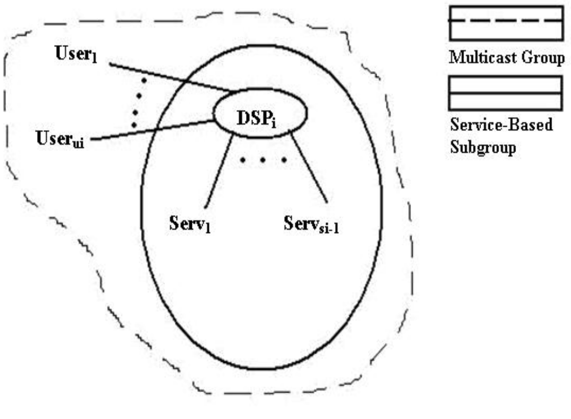

Fig. 3. Service Requested to a Single DSP.

B. Non-Overlapping User, Multiple DSP (Scenario 2a)

Here, users request services from the DSP and the services are not available with the DSP. The DSP, in turn, acts as a broker and gets the required service from some other DSP, which offers the requested services. In the process, DSP becomes a member in the sub-group offering the services and also remains as a part of the original sub-group containing the user-nodes as shown in Fig. 4. This scenario provides services belonging to a different service class than the service class of the sub group, which the requesting users were allotted to, on the first place. In a special case, all the user-nodes in the entire group may request for a single set of services belonging to a specific service class. In such a case, all the DSPs join the sub group, which actually provides the requested set of services. They get the services from the sub group and pass them on to their respective user-nodes through the Leader.

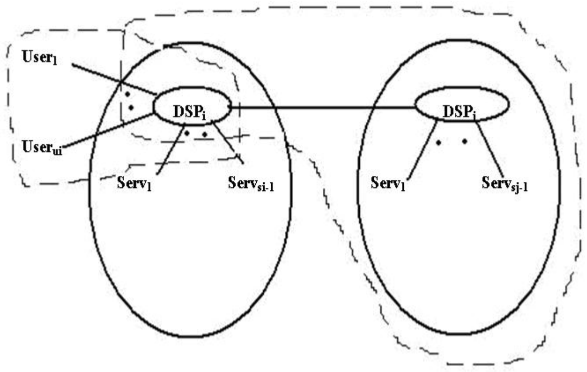

Fig. 4. Non-Overlapping user, Multiple DSP.

C. Overlapping Users, Multiple DSP (Scenario 2b)

Here also, the services requested are not available with the DSP. In cases, where the DSP is busy doing other job and cannot moderate with another DSP to get the service, it can allocate the users directly to the sub-group which offers the requested services. The user-nodes join the multicast group of new DSP, and avail services as in (1), as shown in Fig 5. But, the transferred users remain as part of the original sub-group too. Here also, the serviced users may be requesters of services that were not available in their initial sub group. Sender anonymity is again assured. This scenario services more users than (1), due to the additional members from the other sub groups.

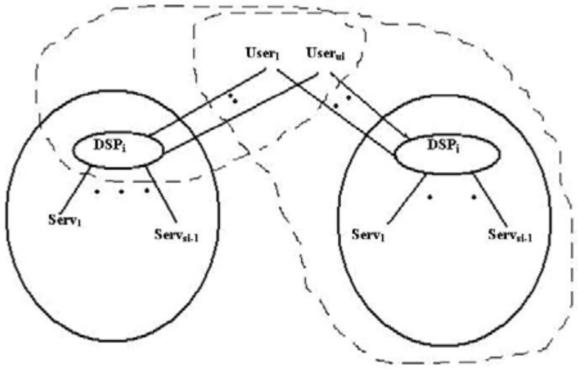

Fig. 5. Overlapping users, Multiple DSP.

6. Membership Events

Having identified the group formation scenarios, it is now necessary to elucidate the Membership events, Join, Leave and Transfer. The stepwise algorithms for these events are presented below. Let DSP denote the set of all Deputy Service providers and

A->B: K [D]

denotes 'A' sending a message 'D' to 'B', using a symmetric encryption algorithm with key 'K', known to both A and B. Let SK_i denote the subgroup key of the i^th subgroup and PK_A denote the private key of 'A'.

D. Join

Step 1: Initial Kerberos authentication using the procedure described in section IV, upto sending of message 3 by the User.
Step 2: $DSP_{i,}$ verifies with $SACL_i$ and if the user is entitled for the services requested, goes to step 7 or else does not authenticate the user and the data transmission is uninterrupted.
Step 3: DSP_i sends an Approval Ticket (AT) to user and triggers KGM of the subgroup leader L_i. u_i becomes $u_i + 1$.
Step 4: L_i updates its subgroup membership database, and generates new subgroup public key SK_i'
Step 5: L_i stops data transmission
Step 6: L_i performs encryption and distributes new subgroup public key as follows. This achieves backward confidentiality. Let $user_k$ denote the k^th user-node in the subgroup.

$L_i \rightarrow user_j$: $SK_i\ [SK_i']$ (Multicast); $1 \le j \le u_i - 1$
$L_i \rightarrow user\ u_i$: $PKuser_{ui}\ [SK_i']$ (unicast)

Step 7: Data transmission resumes and stops only when the session ends or when L_i stops data transmission.

E. Leave

There can be two types of leave events – Voluntary leave and Compelled Leave. The DSP may ask the leader to expel a member from the group if it finds the member unworthy of continuing in the group.

1) Voluntary Leave

Let a user leave the subgroup i.
Step 1: User sends LEAVE message to DSP_i
Step 2: DSP_i approves and sends an approval message to user and triggers KGM of the subgroup leader L_i.
Step 3: L_i updates its subgroup membership database, and generates new subgroup public key SK_i'. u_i becomes $u_i – 1$, with the user being excluded.
Step 4: L_i stops data transmission
Step 5: L_i performs encryption and distributes new subgroup public key SK_i' as follows. This achieves forward confidentiality. Let $user_k$ denote the k^th user-node in the subgroup

$L_i \rightarrow user_k$: $PKuser_k\ [SK_i']$ (unicast); $1 \le k \le u_i$

Step 6: Data transmission resumes and stops only when the session ends or when L_i stops data transmission.

2) Compelled Leave

Let a user be expelled from the subgroup i.
Step 1: DSP_i sends EXPEL message to $L_{i.}$
Step 2: DSP_i triggers KGM of the subgroup leader L_i.
Step 3: L_i updates its subgroup membership database, and generates new subgroup public key SK_i'. u_i becomes u_i - 1.
Step 4: L_i stops data transmission
Step 5: L_i performs encryption and distributes new subgroup public key SK_i' as follows. This achieves forward confidentiality. Let $user_k$ denote the k^th user-node in the subgroup.

$L_i \rightarrow user_k$: $Pkuser_k\ [SK_i']$ (unicast) $1 \le k \le u_i$

Step 6: Data transmission resumes and stops only when the session ends or when L_i stops data transmission

F. Transfer

Transfer can be achieved through Join and Leave. Let an user be transferred from $subgroup_i$ to $subgroup_j$
Step 1: User is expelled from $subgroup_{i\ using}$ compelled leave algorithm
Step 2: User is redirected to $DSPj_{.}$
Step 3: User joins $subgroup_j$ using the join algorithm.

7. Experimental results

The G-LeaSel model, proposed in the preceding sections was analyzed on a test bed built from Open Mosix enabled systems for the following parameters – System throughput, Scalability and Average time taken for Hacking. The results obtained were interpreted and are presented below. Throughput of the model refers to the total amount of data transferred in a given unit of time. It is affected by communication overheads within the system. Scalability is the ability of the model to adjust its performance suitably at different concentrations of users. Scalability of G-LeaSel is analyzed based on the group formation scenarios, proposed in section IV. Average time taken for Hacking is the average time needed by the hacker to disrupt multicast services, by carrying out various kinds of attacks.

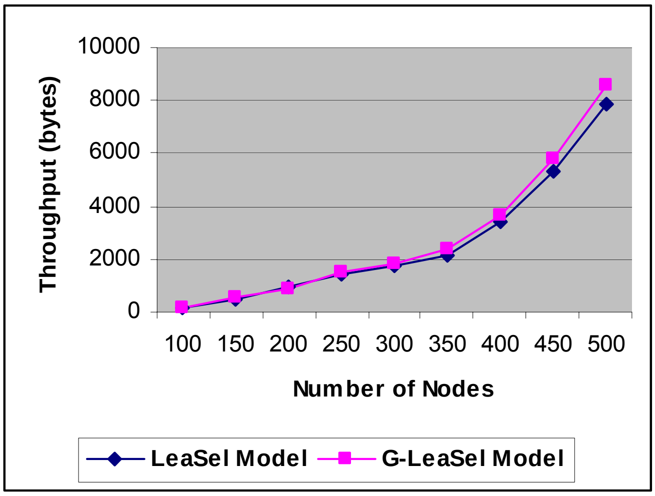

Fig. 6. Throughput of LeaSel vs. G-LeaSel Model.

The system throughput was found to match closely with the performance of the LeaSel model, proposed for wired networks, as shown in Fig. 6. This goes to prove the adaptability of the LeaSel model to grid environment, without any degradation of performance.

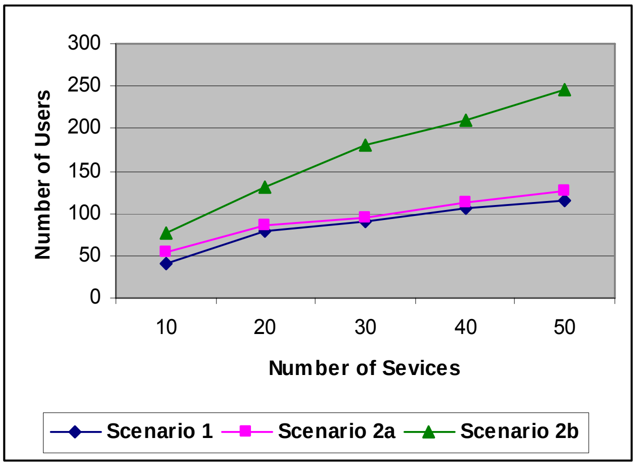

Fig. 7. Scalability of the G-LeaSel Model.

The three group formation scenarios, put forth in section 4, were analyzed based on the number of users; the sub-group provides service to, when the sub-group is formed by each of the scenarios. The results indicate that scenario (1) serves only the users that are initially allotted to it by the controller. On the other hand, scenario (2A) is liable to serve more users than (1) because in addition to the users originally allotted by the controller, the sub-group may include some DSP s also. But, Scenario (2B) supers (2A) because the sub-group can include users from other subgroups in addition to the users allocated originally. Since the number of DSP s are quite small compared to the number of users in a sub-group, there is a drastic increase in the number of users serviced in case of (2B). These implications aver that the model is scalable, under various modes of group formation as shown in Fig 7.

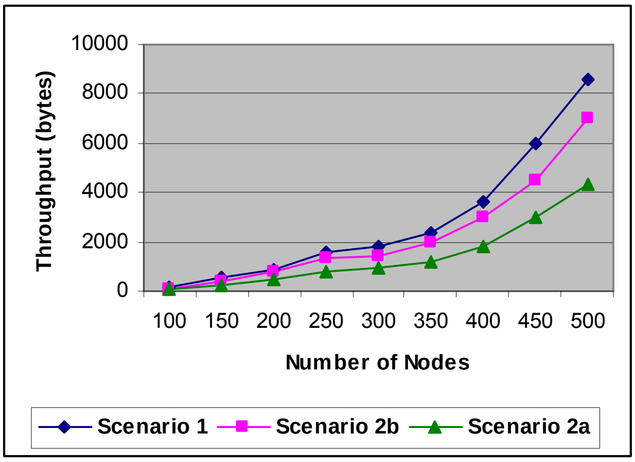

Fig. 8. Throughput based on Group Formation Scenarios.

The throughput was also measured separately for subgroups formed based on the different group formation scenarios. The results presented in Fig. 8, indicate that (2A) provides the lowest throughput since it involves considerable overhead at the DSP, in getting the service from another subgroup and then multicasting it to its users. (1) Offers the best throughput since it involves no additional overhead. (2B) offers an intermediate level of throughput since it involves some overhead in transferring the users to the subgroup, where the requested service is available.

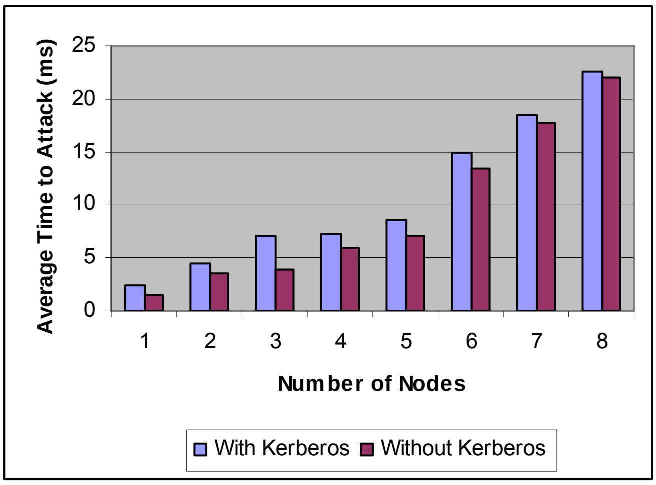

Fig. 9. Average time taken to attack the Leader with Kerberos and Without Kerberos in the system.

The model was also tested by introducing Hackers into the system. The Hackers carry out various security attacks. The average time for attack was measured under two conditions, namely with and without Kerberos. It was found that the average time to attack was higher when Kerberos was incorporated, as shown in Fig. 9. The single sign-on mechanism of Kerberos requires the use of a host’s private key only once. Hence, same TGT can be reused for different services and possibility of spoofing by capturing authentication data is reduced greatly Moreover, the model hides dynamically changing services behind the Controller (acting as AS) and any external hacker can get into the system only after a breaking a rigid authentication protocol. This indicates that the model benefits from the use of a proven authentication protocol and offers stable performance under different circumstances.

8. Conclusion and Future Work

Thus, G-LeaSel with Kerberos as authentication protocol strengthens up the security level of the system and proves to be a potential choice for a secure multicast security model for grid. This is an encouraging step forward towards solving the security problem for a wide class of applications. Future work involves analyzing the existing security features of grid further, to study more closely the overheads involved when using them for group communication. This basic model may be optimized to give improved performance and also support more sophisticated service allocation schemes. Future research will also be targeted at solving resource allocation problems within this model using operation research techniques.

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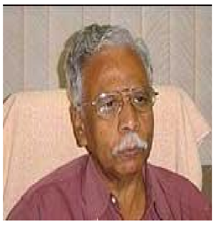

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