Interacting with Learning Objects in a Distributed Environment

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Abstract

Learning Objects are gaining an increasing interest in the e-learning community. Their availability in a distributed Web-based environment represents an opportunity for further developments generated by a richer context of interaction that permits to different stakeholders to use, comment and evolve available objects, thus providing each other with suggestions and insights. In this paper we propose a distributed scenario in which users may express their comments about Learning Objects, point out relationships among them, and evolve a Learning Object in the sense of specialization. The implementation of such environment in a Super Peer Network is outlined together with basic exploration facilities.

1 Introduction

Learning object (LO) technology [1] seems to offers a viable solution to the problem of reducing the high cost of production of good quality educational material [2].

Via this technology, in fact, a systematic approach to the creation of resources to be accessed via the electronic network is proposed. The approach aims to endow a learning material with properties that allow its efficient localisation, retrieval, reuse and adaptation to a variety of instructional environments, independently of the creation context. A course, or, more generally, an instructional proposal, is viewed as a set of instructional units: each one is self-consistent, endowed with precise educational objectives, and can be repurposed. To realise this idea, a description of the content (usually called metadata) as to educational features, context of use, technical aspects is associated to these instructional units. To render it possible to find, retrieve, select, sharing and manage such units, descriptions are based on standards generally accepted [3].

A learning object was defined by the Learning Technology Standard Committee (LTSC) of the Institute of Electric and Electronic Engineers (IEEE) [4] as 'any entity, digital or non digital, that may be used for learning, education or training' [5]. This broad definition was then elaborated in various ways, reflecting different aspects of interest [6]. There are still various views; however, a number of authors relies on the IEEE definition, limited to digital resource that are at disposal for reuse, in particular via the electronic network [7], [8]. According to this view, learning objects are, for example, Web pages, pdf documents, Java applets, and so on.

The promising perspectives of the LO paradigm gave a considerable impulse to the work aimed to devise international standards for learning technologies, so to guarantee reusability, interoperability, accessibility and durability of these kinds of resources [9], [10]. In this area, the metadata field is particularly active. We recall here, as an example, just the Learning Object Metadata (LOM) proposal [5], which is the learning object metadata scheme promoted by IEEE Learning Object Standards Committee, resulted from the joint effort of several initiatives in the field. It was approved as IEEE-SA standard in June 2002 [11].

The standardisation work has been accompanied by a considerable activity on the methodological side, aimed to find solutions to the user problems that still limit the exploitation of the learning object technology, in particular as regards the instructional point of view [12]. Despite these difficulties, the interest for the LO paradigm [13] led to a number of applications in the context of both training in companies and institutional education. As to companies, we note that LOs are extensively used by a number of corporations; for example, Cisco, Microsoft, AT&T Business Learning Services adopt this approach for internal training and customer certification programs

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[14], [15]. At academic level, numerous national and international initiatives led to the realisation of structures aimed to facilitate the sharing of materials among institutions and their corporate partners [16], [17]. We recall, as an example, the project Merlot (The Multimedia Educational Resource for learning and on-line teaching), that realised a repository free of charge and aimed to provide on-line resources for faculty and higher education students [18]. A notable feature of Merlot is the quality guarantee it offers, at least at some level, for the LOs that it offers [19]. At European level, we recall the system ARIADNE (Alliance of Remote Instructional Authoring and Distribution Networks for Europe), that was developed within the homonymous project: it comprises a distributed repository of pedagogical documents (learning objects) that differ as regards content, type, granularity [20]. They are stored for possible reuse in telematics-based training or teaching, in companies and academic contexts [21]. The development of the web and the availability of distributed systems represent an opportunity for the e-learning community, and the availability of a learning object on the web increases its significance and its potential impact on different users. At the same time, by exposing a learning object to a wider audience, a higher number of feedbacks that will permit to improve the quality of the object can obtained.

However, the experience gained in the work on learning object repositories (LORs) highlighted the difficulty of creating a critical mass of high quality material easily accessible from a number of communities [22].

To overcome this difficulty, efforts have then been oriented towards the issue of efficiently interrelating distributed and heterogeneous repositories. An example is constituted by the Global Learning Objects Brokered Exchange (GLOBE) alliance [23], that aims to create a network of linked and interoperable repositories. Another example is the eduSource project, a joint venture of Canadian partners aimed to create the prototype for a network of interoperable LORs [24]. Methods for realising a Distributed Learning Object Repository Network, aimed to limit the barriers to the access to LOs, are also proposed [25].

To create a critical mass of high quality material, in our view, LORs should moreover be endowed with features that support motivation for users/teachers to put their time and effort in usage, implementation and diffusion of LOs. As already noted, in fact, sharing didactical materials is no straightforward task for teachers, but requires of them a good amount of labour both to integrate in their own lessons other people's productions and to prepare new contributions in a form that can be easily re-used and adapted by their colleagues [26]. On this basis, we suggest to regard at LORs as a foundation for developing a network of communities of practice, that produces valuable ideas and new artefact as a result of the experience gained dealing with LOs [27].

Accordingly, in this paper, we focus attention on the design of an adequate environment that permits to a distributed community of users to interact with distributed learning objects in an efficient and effective way. In Section 2 we outline the interaction patterns that occur in a community of practice centered on LOs. We then examine candidates architectures for the support of these interactions in a distributed environment (Section 3). In Section 4, we shortly outline a Super Peer Network based implementation of such a system.

2 Interacting with learning objects

Referring to [28, page 5], with the expression 'communities of practice' we mean *groups of people who share a concern, a set of problems, or a passion on a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis*. From a structural point of view, a community of practice is '*a unique combination of three fundamental elements ...: a domain of knowledge, which defines a set of issues, a community of people who care about this domain; and the shared practice that they are developing to be effective in their domain*' [28, page 27]. In our case, the domain of knowledge is constituted by the LOs at disposal, the community of people by their users, and the shared practice is made of the users' opinions and experiences about possible uses and relationships of LOs. The issue is that of exploiting the potential of LOs by supporting users in selecting and reasoning on LOs at the light of the subjective views of the members of the community. Users, moreover, are usually organised in local communities (universities, corporations, etc..).

To realise a network of these kinds of communities (namely a *network of practice*), LOs should be enriched with the expressive power deriving from the interactions with both the users and other LOs. Accordingly, we introduce the following levels of interaction between a user and a LO:

- A 'reflection level', represented by the variety of users' opinions about the LO;
- A 'interconnection level', represented by the conceptual network of LOs, including the LO at hand, dynamically created by users during the search and the interaction process.

Each of these levels may further include different kinds of relationships (see Table 1).

Table 1. The levels of interactions between a user and LOs

Level	Kind of relation	Example
Reflection	Peer review (**P**)	The opinion of an expert officially entrusted with the task
	Results of the experience (**R**)	The description of a domain where the object has been used and the students' reaction
	Opinion (**O**)	The opinion of a user
Interconnection	Specialisation (**S**)	LO_j is indicated by a user as a specialisation of LO_i if, for example, the user thinks that LOj could be used to go in deep or to show an example of a concept which is tackled by LOi.
	Complementary (**C**)	LO_j is indicated by a user as a complement of LO_i if, for example, the user thinks the two LOs can be coupled in the same context or she/he experienced this use
	Affinity (**A**)	LO_j is indicated by a user as similar to LO_i if the user think that LO_j and LO_i could be used interchangeably

This view leads us to interpret each LO as an *annotated graph* of both the connections between users' reflections on it and the interconnections, as seen by the users, between the LO at hand and other LOs in the network (See Figure 1). LOs are identified by nodes. Interactions between user and LOs are identified by means of *interaction arcs*, labelled by tuples of the form *<User, Relation, Comment>,* where:

- *User* is any suitable reference to identify the user annotating the object;
- *Relation* is the identifier of the relation being established for the object, where *Relation* pertains to the set {P, R, O, S, C, A};
- *Comment* is the annotation associated to the relation. The comment can be expressed in textual, audio-visual or mixed form.

In the labelled graph of Figure 1 four relationships are represented for learning object LO_p: two reflections about LO_p, an opinion (O) and a peer-review (P), created by users U_k and U_i respectively; a specialisation (S) suggested by user U_i about learning object LO_q with respect to LO_i; and a complementarity (C) with learning object LO_t individuated by user U_j. For the sake of simplicity the *Comment* elements aren't shown in the tuples of Figure 1.

The interaction arcs linking the LOs establish a *graph of comments* and relationships which enforce, with new meta-knowledge, the LORs provided by the participants to the network of practice. The kinds of interactions existing between LOs and users, as expressed by the graph of comments, are almost the same that occur in a distributed environment where users and LOs are located in different sites and connected via a communication network, as in the case of Internet.

In the following we examine some suitable network infrastructure on the basis of which we introduce our proposal to implement the graph comments.

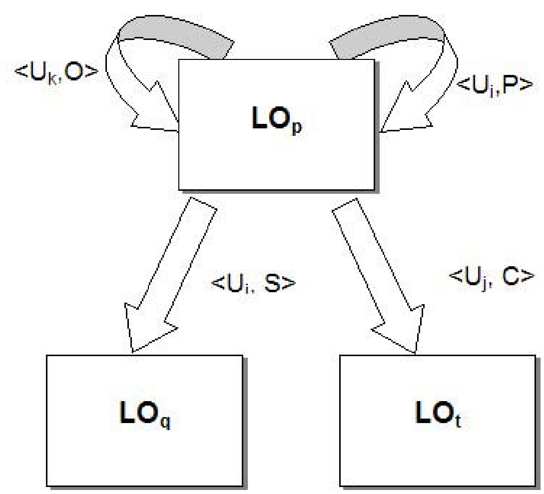

Figure 1. Graph of comments for learning object LO_p

3 Peer to Peer and Grid architectures for Learning Objects

There are two emerging architectures that may be considered as natural candidates to represent the

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supporting environment for distributed learning objects: the Grid and Peer to Peer.

3.1 Grid

The Grid [29] is the reference architecture for the implementation of Virtual Organizations. A Virtual Organization is constituted in order to pursue a well defined goal, like to obtain an impressive computing power by sharing computing resources available at different sites, to store and share an impressive amount of data like those produced by advanced physics experiments [30], or to share knowledge about a specific topic [31]. Different physical organizations participate to the Virtual Organization and share a set of common rules, while preserving their own policies.

The Grid middleware provides many different services that include at least resource sharing and discovery, security and authentication, information service and data management. Moreover, the Grid middleware may provide a support to fault tolerance, and ensure certain level of reliability and availability for example by means of replication.

There are different research projects aimed to exploit the Grid for e-learning and virtual laboratories implementations. A partial list includes [32], [33], [34].

In our opinion, despite the Grid supports a view based on dynamic interactions, we may look at it as an "heavy weighted" architecture that is particularly suitable to share resources at the organization level and with a well defined goal, that requires a quite stable and long lasting environment. In this context individuals are expected to be users of the infrastructure that however exists independently from their contribution. This may represent a limit for the considered application, where resources are provided by individuals that decide to share them.

3.2 Peer to Peer systems

On the contrary Peer-to-peer emerged as a light-weight interaction paradigm finalized to share resources (like music files) among individuals in a rapidly changing environment [35]. In this case the system provides basic services like those necessary to know who is on and what resources are available, while other aspects like security and authentication are usually not addressed.

Also Peer-to-peer attracted the attention of researchers involved in e-learning and different proposals and research projects where developed in the recent past [22], [36]. One of the key issues addressed by different studies is the definition of a suitable metadata organization in order to provide interoperability of heterogeneous learning objects. Here we don't consider this aspect.

An important consideration by our point of view is that a Peer-to-peer system exists because the individuals participate to it. In some cases this may introduce a problem of availability of resources that may jeopardize the finality of the system. In fact if the Peer-to-peer community is finalized to share widely available resources (for example music file of rock stars) then the availability of a specific resources is normally ensured by wide replication. On the contrary, when each individual contributes with her/his own specific resources that are different from those of other users, then the system may provide its services and attain its goals only if a sufficient number of users is connected. This may be the case of learning objects.

The same problem can be considered by another point of view. In fact the use of a pure Peer-to-peer system makes it possible to access to the contribution of an individual only if this is connected to the system, otherwise its contribution is lost. Again this is not a problem when many individuals provide the same resource, but it represents a notable limit when different individuals provide different contributions, like in the case of learning objects.

The research on Peer-to-peer systems has led to a broad distinction of existing systems that are classified in two main groups: pure and hybrid Peer-to-peer. The first category is characterized by the fact that it represents true distributed systems in which all the nodes are equal and there does not exist any form of centralization. In principle these systems are scalable and fault tolerant but they turn out to have some heavy performance limitations, e.g. due to the necessity of interacting with all the nodes of the network when executing a query (network flooding). Another weak point is that, being the environment heterogeneous, slow nodes may become the bottleneck of the system. Examples of pure Peer-to-peer are Gnutella [37] and Freenet [38].

Hybrid peer-to-peer introduces some form of centralization at least to keep an index or directory of relevant information. In this case scalability is ensured only if the centralized service (e.g. the directory service) is able to scale up with the growing of the network, otherwise it will become the bottleneck of the system and in some case it may give up. At the same time the centralized resource may become a single point of failure for the system. An example of hybrid system is represented by Napster [35].

The advance of research on Peer-to-peer architectures has led to the proposal of Super Peer Networks (SPN) [39]. This proposal is mainly motivated by performance considerations. We consider this architecture in the Section 4. It is important to say that SPN as a support architecture to share LOs has been considered also by researchers involved in the Edutella project [40]. Again their emphasis is mainly on efficiency of the query mechanism, while we look at SPN also as a way to improve availability of information about comments on LO and to permit asynchronous interaction between peers.

4 A Super Peer Network for interacting with LOs

Super Peer Networks try to combine the better aspects of both worlds by introducing specific nodes, namely *super peer nodes* (SP nodes) that act as a query server with respect to a set of clients (normal peers) and as peers with respect to the other super peer nodes. Each client node is connected exactly to one super peer node. This means that each client to post a query has to interacts only with its super peer node, which in turn interacts with other super peers in a canonical Peer-to-peer fashion (i.e. by passing requests to its neighbors SPs). The popular file sharing site KaZaA [41] is based on this architecture.

In this network we may look at super peers as equals for the search and to all peers as equals for downloading.

In Figure 2 a SPN, formed by five SP nodes and by their connected clients, is schematized. For each SP node, the thick lines connect it with its neighbors.

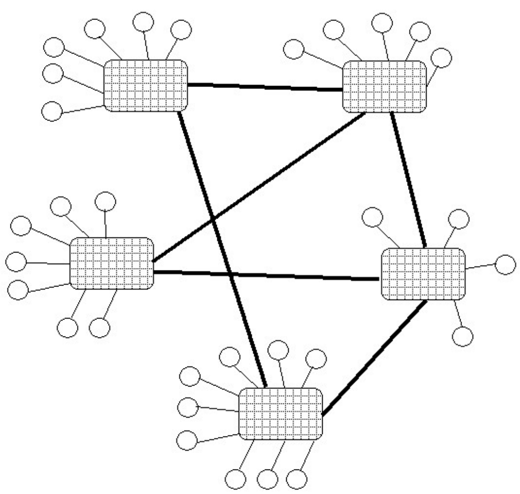

Figure 2. A Super peer network

Experiments show that well-balanced super peer networks, may outperform both hybrid and pure peer-to-peer systems as regards of efficiency, robustness and scalability [42].

All these aspects lead us to choose a SPN as a particularly suitable solution to solve both the collaborative-pedagogical requirements (e.g. sharing, discussing, mining, and updating heavyweight comments widespread on the network) and the technological constraints (distributed nature of the communities and heterogeneity of clients machines) emerging from our network of practice.

However, from our point of view, performances are not the only motivation to adopt SPN as the reference architecture. Instead, each super peer node is expected to provide a high level of availability and the network of super peers is expected to be stable. In this way a SPN may represent a sort of distributed black board, on which peers post information about their comments.

In a SPN generally peers represent the active entities of the network, while SP nodes provide the support infrastructure:

- A peer node may dynamically connect (*join*) and disconnect (*leave*) from the network;
- A SP node is supposed to be always connected to the network or at least it has long-life with respect to peer nodes;
- A peer node holds local information;
- A SP node uses one or more indexes to hold meta-information about the local content of each peer connected to it and uses these indexes to process the queries for its clients;
- A SP node adds and removes from its indexes the metadata referring to a peer, each time the peer executes a *join* or *leave* primitive to connect to or disconnect from the network.

From the previous points it follows that, at any moment, the information seen by users of a SPN, exclusively depends on the peers actually connected.

In our case, a SP node is mainly characterized on the basis of its functional role in the network of practice. For example, if a university department participates to the network it is expected that it provides at least a SP node. Each professor/student of the department that participates to the network is a peer connected to that specific SP node. Hence the relationship between a peer and its SP node is normally statically defined.

To realize the graph structure of Figure 1, each comment generated by a peer is stored in a file on the peer node. The information labelling the interaction arcs relating to the comment, namely a *comment-tuple*, is maintained on the associated SP node.

Before discussing the form of the comment-tuples, we observe that, as mentioned in Section 3, the peculiar nature of our application (i.e. a limited number of individuals, each providing its own specific contributions that vary from those of the other users), quite differs from that of a standard SP network application. In fact it is normally intended for the sharing of a huge amount of possibly redundant files by a wide community of users. Consequently, by following the baseline pattern, a rather reduced set of information (comments) shall be returned to a querying user.

To overcome this limitation, a SP node has to hold further and more detailed meta-information about the comments located on its client nodes. When a peer leaves the system, meta-information about its comments will be returned, if it is the case, in response of user searches. Accordingly, comment-tuples are of the form <*User,Relation,Object1,Object2,FileName,ExtraInfo*>. Note that *Relation* is an identifier denoting one of the six relationships defined in Table 1, *Object1* and *Object2* are the URIs of the learning objects involved in the relationship (the same URI in the case of the "Reflection" relationships) commented by *User* and stored on the peer location expressed by *FileName*.

ExtraInfo extends the comment-tuple with further meta-information (e.g. user properties, comments properties, keywords, …), that allows to maintain at users' disposal some kind of "asynchronous view" of the overall graph of comments and relationships built upon LOs by all peers of the SP node. To realize this asynchronicity, furthermore, appropriate changes to the standard *join* and *leave* operation are necessary. In this way users will be supplied with a paramount, though not exhaustive, view of the resources potentially at disposal.

When a peer creates a new comment or defines relations between LOs, the operation is performed by the peer in its local environment, and an adequate information about the operation is transmitted to the SP node that is responsible for the publication of the information on the network.

When a peer queries the network for the comments associated to some LO, SP nodes will supply the complete comments for the connected peers and, by using the extra meta-information, some useful hint about the comments produced by disconnected peers. Thus, a better view of the whole collection of comments is provided.

Let us examine, through the UML collaboration diagram of Figure 3, the main interactions occurring between peers and SP nodes, deriving from users activities.

When a user (namely $user_i$) joins the network, a `connect` message (1) is sent by the Comment manager of the peer node. This message causes the activation of the PeerConnection service running on the associated super peer $node_z$ (1.1). This service adds $user_i$ (via the `add user` message 1.1.1) to the list of the connected peers (1.1.1).

A symmetric approach is adopted when $user_i$ leaves the network . A `disconnect` message is sent (4) to the SP node $node_z$, $user_i$ is then removed from the list of the connected peers of super peer $node_z$ (4.1.1). It can be noted that our implementation of the *join* and *leave* primitives differs from their baseline behaviour (i.e. adding and removing respectively client metadata on SP indexes).

When $user_i$ creates a new comment, the Creation service is invoked (2). After the editing (2.1), the comment is saved by the Creation service on the $user_i$ file system (2.2). A `publication` message (2.3) is then sent to the Comment service running on the SP node $node_z$. The associated comment-tuple is then sent along with the message and stored in the Comments directory of $node_z$ (2.3.1).

Figure 3 illustrates the expected behavior of the system when a peer, specifically $user_k$, browses the network. When the `send query` message reaches the SP node $node_z$ (3), its Browsing service activates a local (3.1) and a global search (3.2). The LocalBrowsing service looks the Comments directory for the comment-tuples satisfying the query condition (3.1.1). The resulting set is then partitioned in two subsets corresponding respectively to:

a) the tuples inserted by peers actually connected to SP $node_z$ (filtered by a scan of the Connected peers list 3.1.2);
b) the tuples inserted by disconnected peers.

For each element in the first subset, a `get comments` message sent to the corresponding peer (3.1.3.1), (3.1.3.2) retrieves the entire comments (i.e. files). These files are returned to the querying peer $user_k$ (3.4), together with:

a) the content of the ExtraInfo field of the tuples pertaining to the second subset (i.e. the comment-tuples of the disconnected peers);
b) all the other elements (files or metadata information) resulting from the browsing of the neighbours of super peer $node_z$ (3.2.1) operates by the GlobalBrowsing service.

5 Concluding remarks

We propose to employ SPN technology as architectural basis to support the development of a distributed network of practice oriented to e-learning and centred on LOs. In this kind of network, the shared practice is made of the users' comments about possible uses and relationships of LOs. As individuals contribute with their own specific resources, the technological structure supporting the network of practice has to guarantee, at every moment, availability of the overall graph of comments and relationships built upon LOs by all peers, including contributions of peers which are not connected.

We discussed the opportunities offered by SPN to tackle this problem, we individuated functionalities that allow to deal with it, and we outline an architecture. The discussion was based on an analysis of the interaction patterns that occur in the network of practice considered. A prototype of the proposed solution is currently under implementation

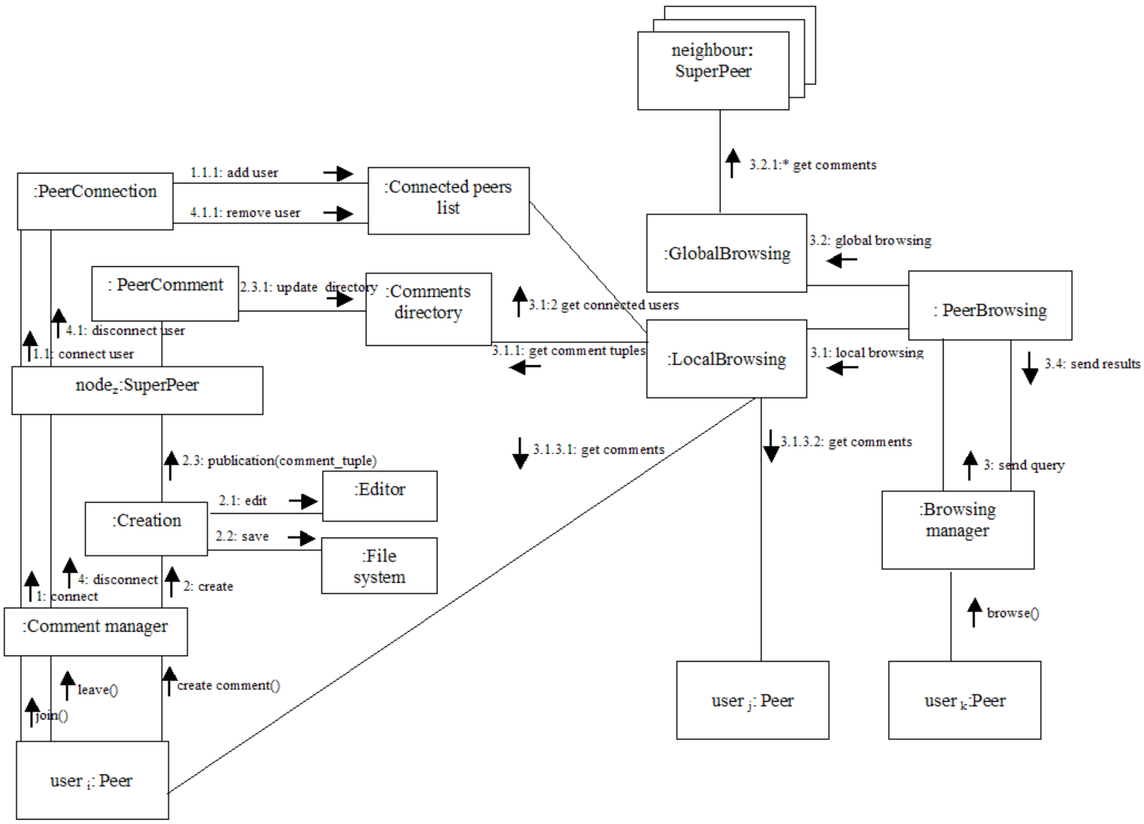

Figure 3. UML collaboration diagram on the interactions between peers and SP nodes

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